

Chaire Informatique et sciences numériques



# Des images médicales au patient numérique

**Nicholas Ayache**

*10 Avril 2014*

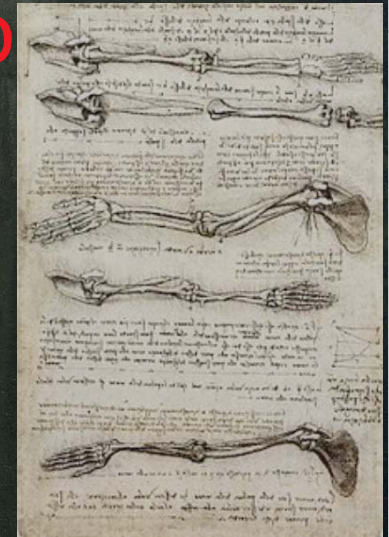


Le patient numérique personnalisé  
Images, médecine et informatique



COLLÈGE  
DE FRANCE  
—1530—

# La leçon d'anatomie du Dr Tulp (Rembrandt, 1632)



Léonard de Vinci, 1510



## Musculoskeletal System

Dinesh Pai, Rutgers



... 1895...



**1901** : Wilhelm Roentgen  
Premier prix Nobel de physique

# Aujourd'hui

**TDM (scanner)**



**IRM**



**TEP**



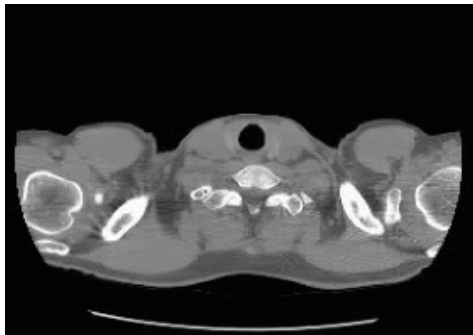
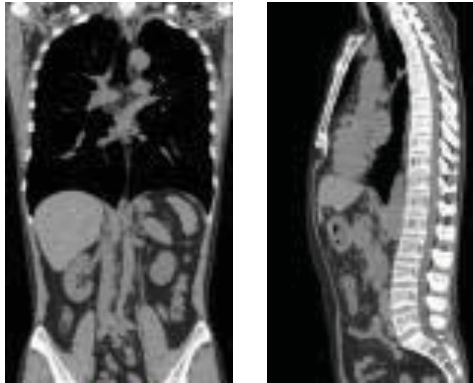
**Echographie**



# Structure et fonction

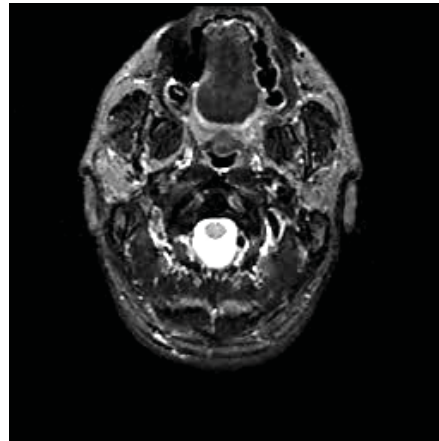


TDM (Scanner X)

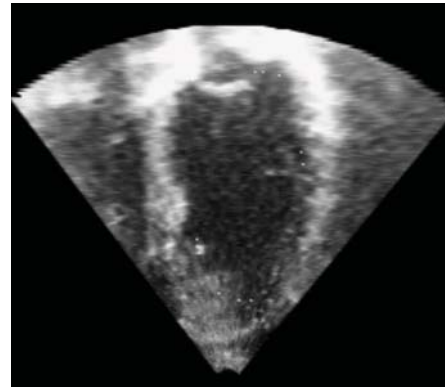


Source :H. Fujita

IRM

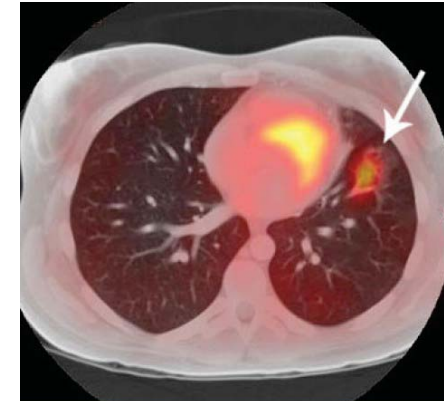
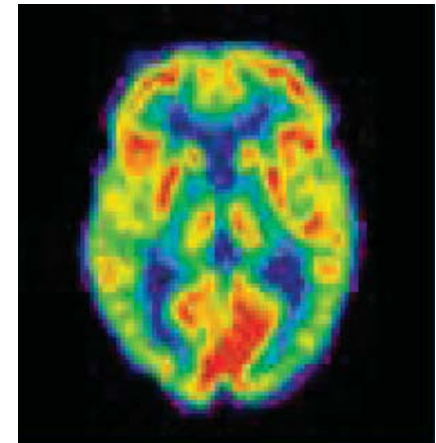


Echographie



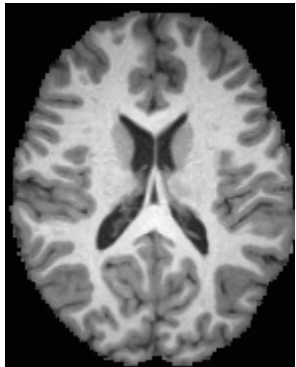
Source :T. Peters

TEP

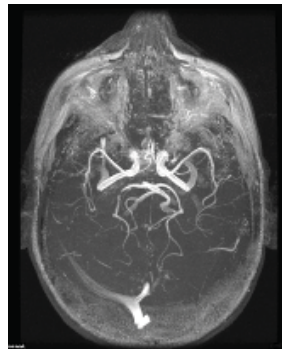


# Richesse de l'IRM

anatomique



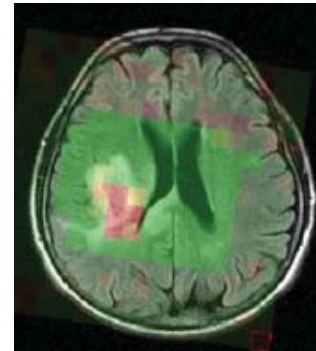
angio



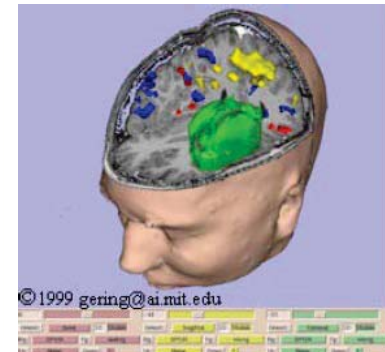
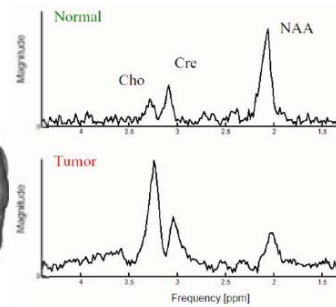
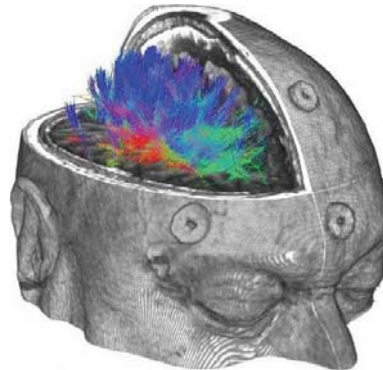
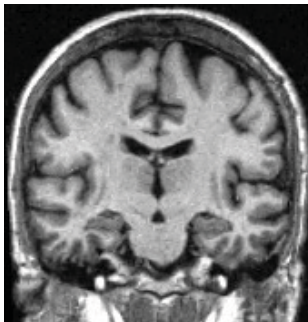
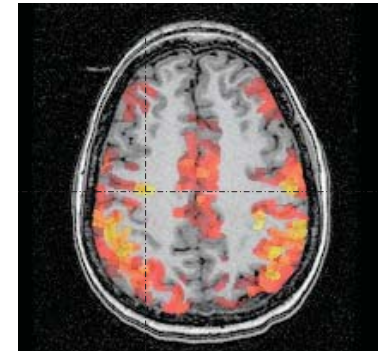
diffusion



spectro



fonctionnelle



D. Le Bihan, Le cerveau de cristal, 2013

# Plus d'images



- Elastographie (IRM, US, etc.)
- Endomicroscopie confocale
- Tomographie de cohérence optique (OCT)
- MEG, EEG
- etc.



Supersonic Imagine, Biospace, Eos Imaging, Mauna Kea Technologies,...

M. Fink, Leçon inaugurale 2009

Nicholas Ayache  
10 avril 2014

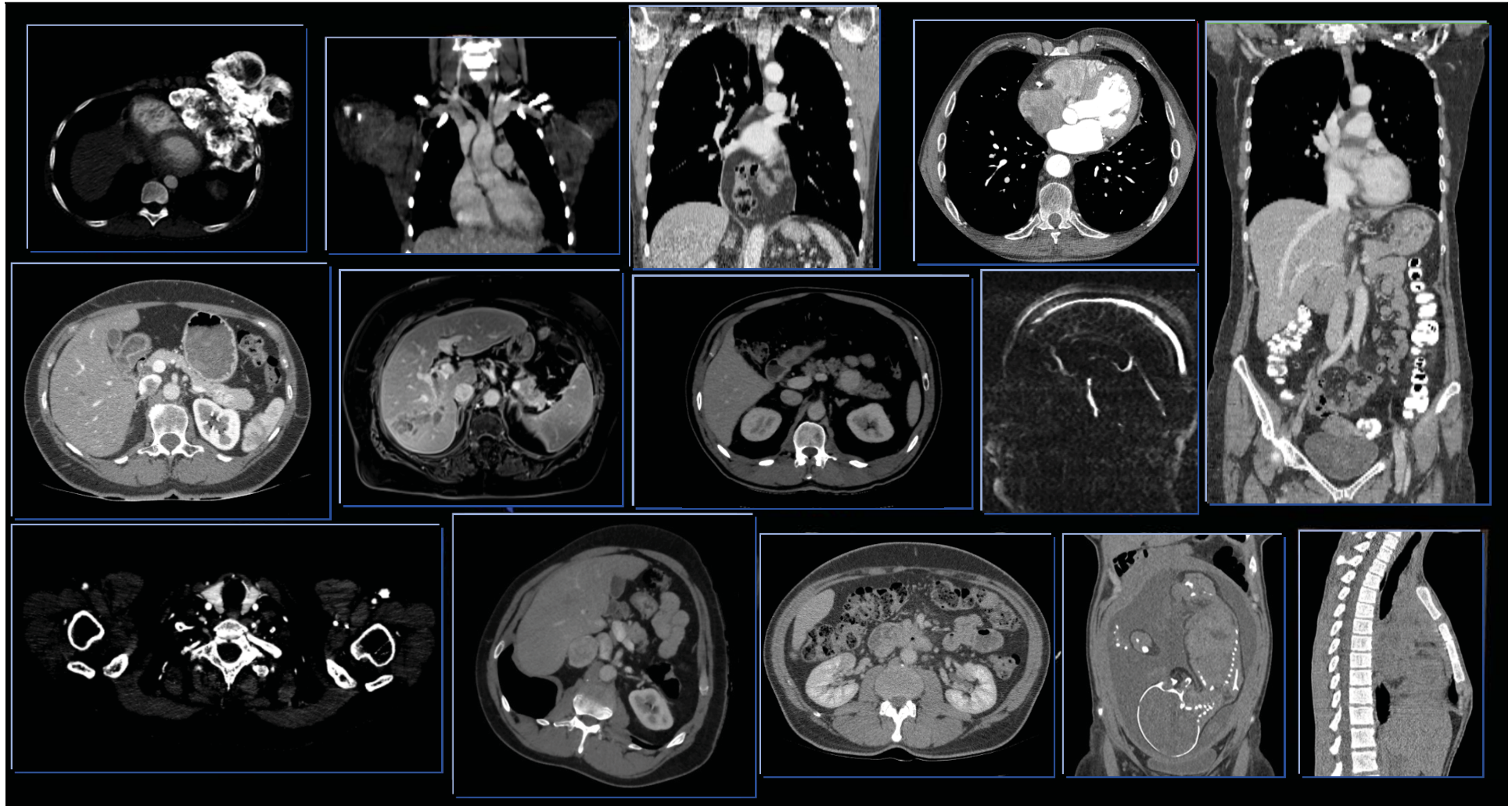
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# Big Data



L. Soler, Visible Patient

Nicholas Ayache  
10 avril 2014

Des images médicales au  
patient numérique

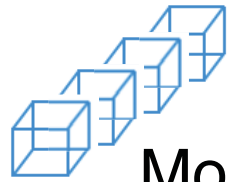


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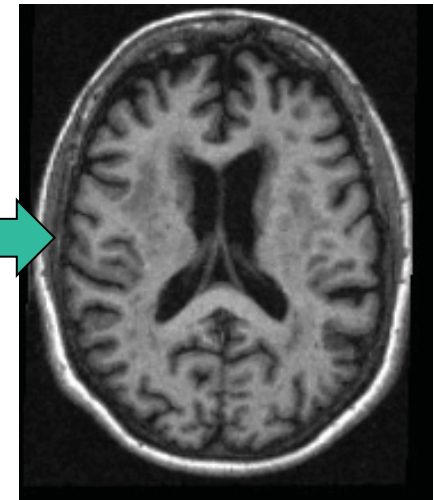
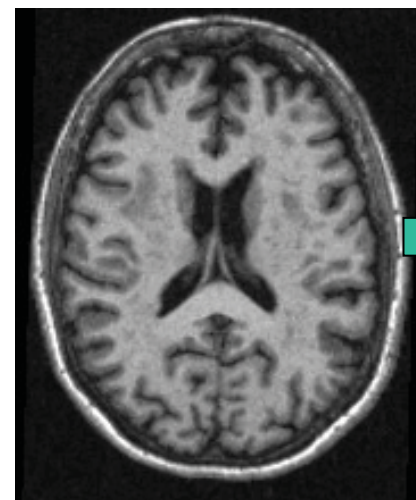
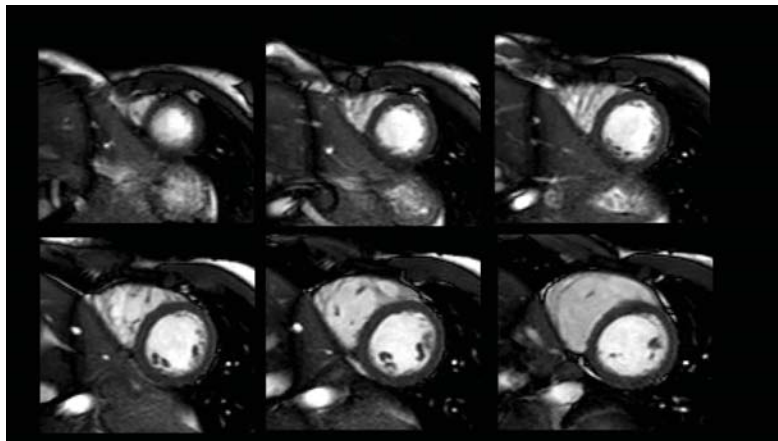
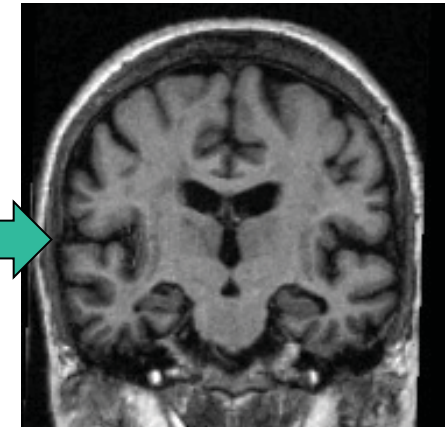
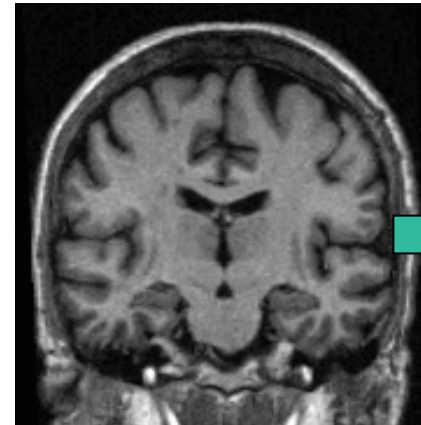
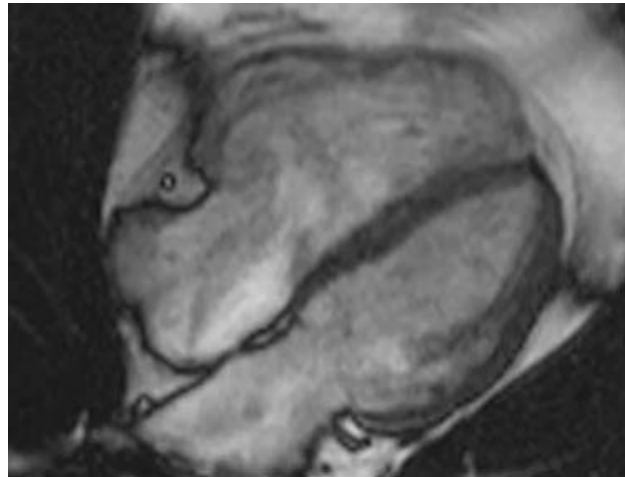
Mouvement

# Images 4-D

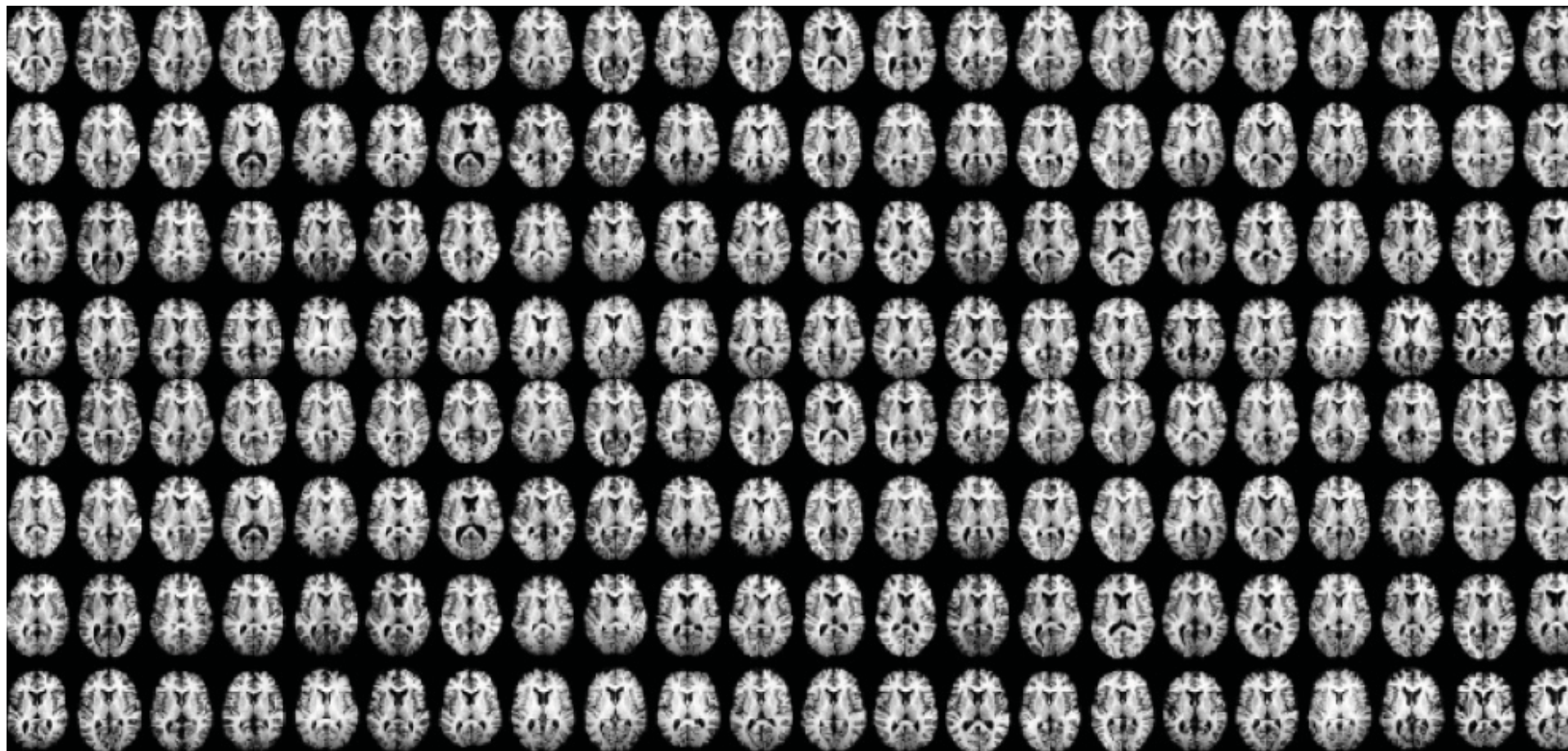
Evolution

Date 1

Date 2



# Sur la Toile



S. Abiteboul, Leçon inaugurale 2012

Nicholas Ayache  
10 avril 2014

Des images médicales au  
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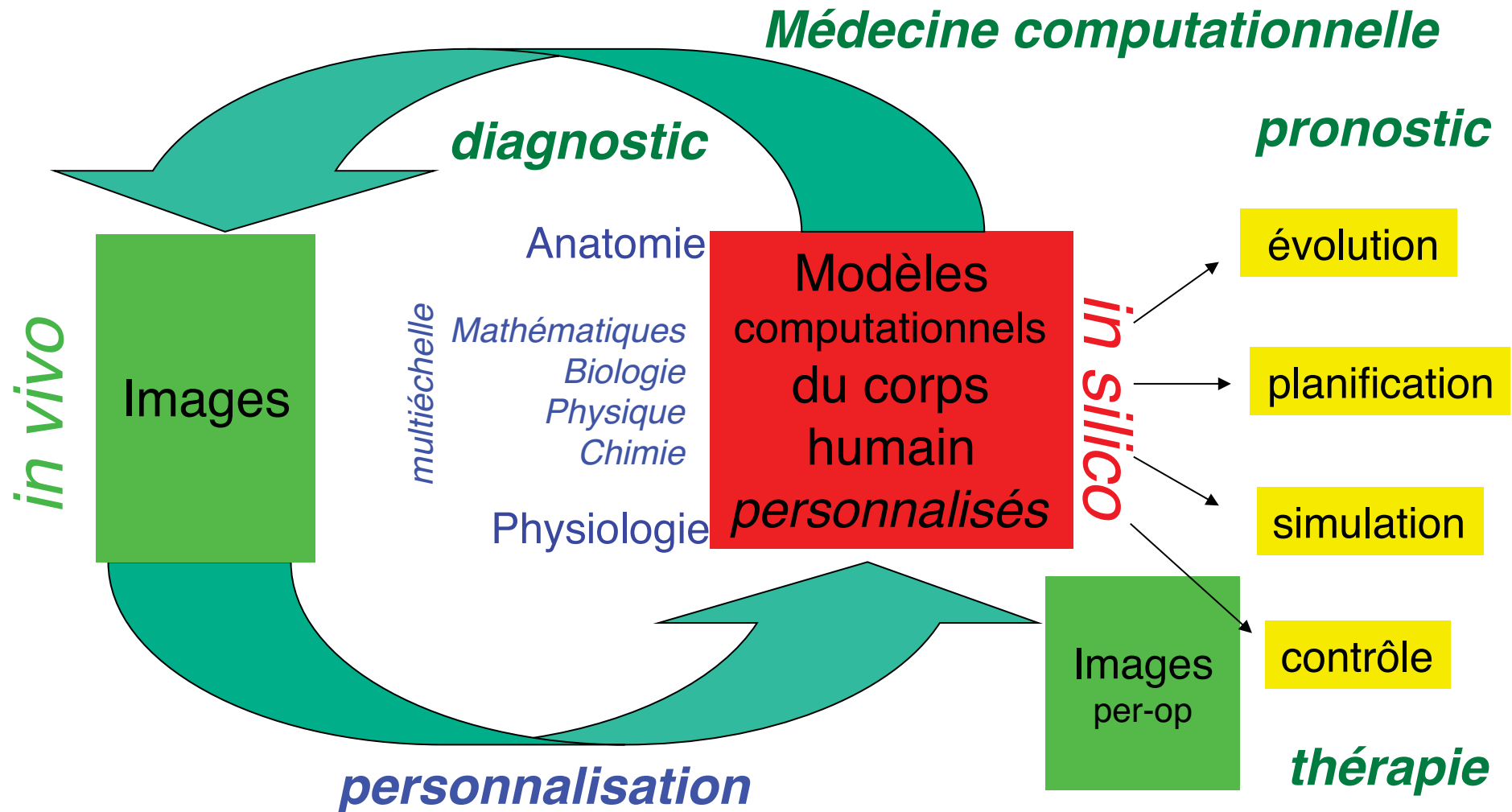
10

# Informatique et sciences numériques

- Extraire **information** *cliniquement pertinente*
- La traiter dans *un cadre unifié*

Patient numérique

# Patient numérique



- N Ayache, P Ciarlet , JL Lions (Editors) Computational Models for the Human Body, Elsevier, 2004
- N Ayache, A Frangi, P Hunter, R Hose, I Magnin, M Viceconti et al. Towards Virtual Physiological Human, European White Paper , 2005

# Salle d'intervention du futur

Images pré-opératoires

Modèles numériques du patient

Planification et simulation  
Réalité virtuelle

Imagerie per-opératoire

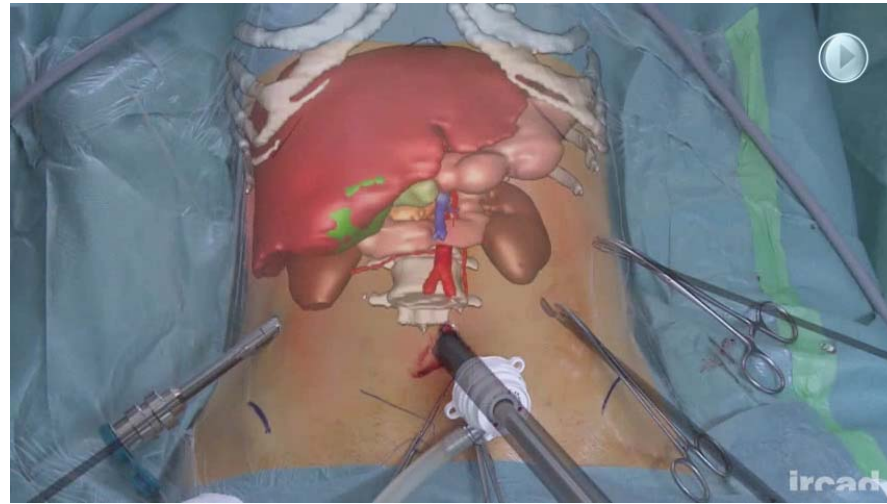


IHU Strasbourg  
*J. Marescaux*

Thérapie robotisée

Réalité augmentée

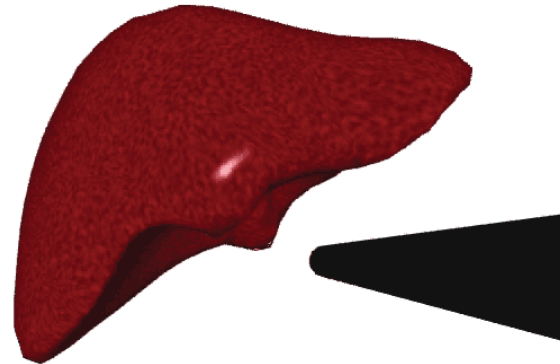
# Réalité Augmentée



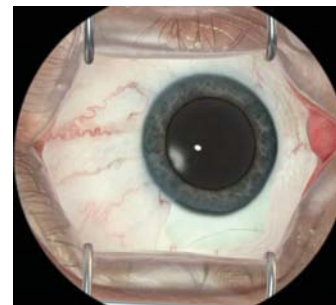
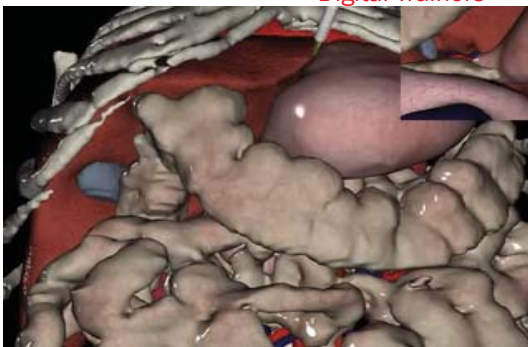
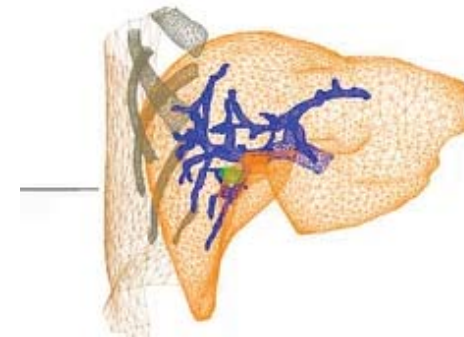
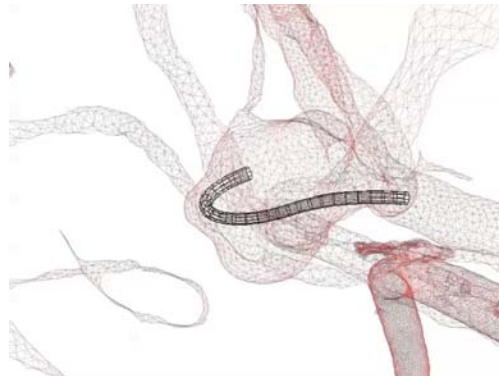
# Réalité Virtuelle



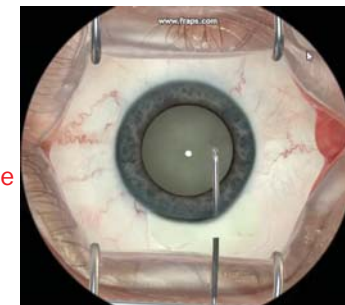
S. Cotin et al.



Digital Trainers



HelpMeSee



# Science des images médicales

## *Applications cliniques*

Radiothérapie

**Chirurgie**

**Cardiologie**

Oncologie

Radiologie

Orthopédie

**Neurologie**

Psychiatrie

Sénologie

**Gastroentérologie**

**Endoscopie**

**Dermatologie**

Anatomopathologie

**Gynécologie**

**Urologie**

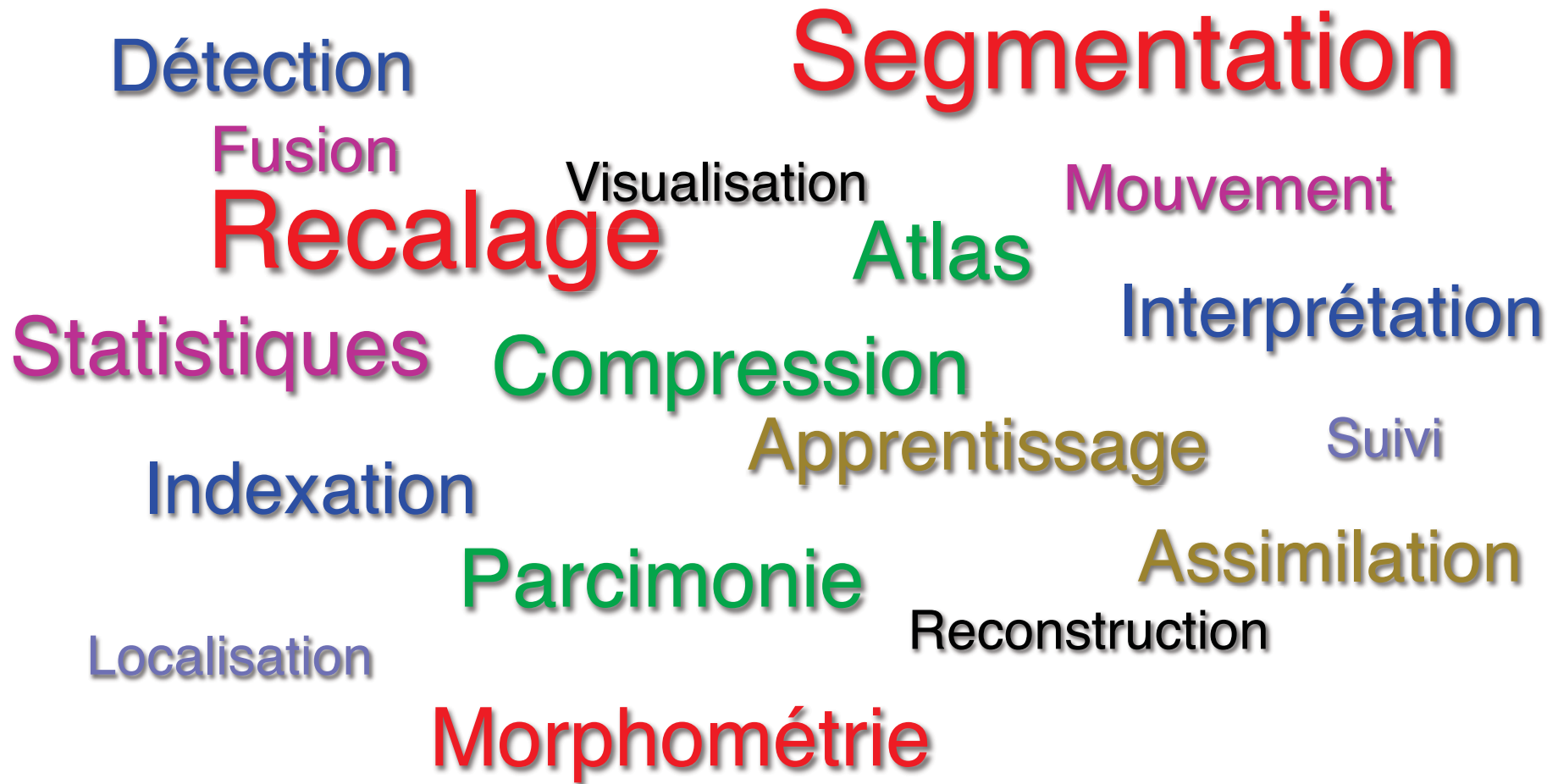
Ophtalmologie

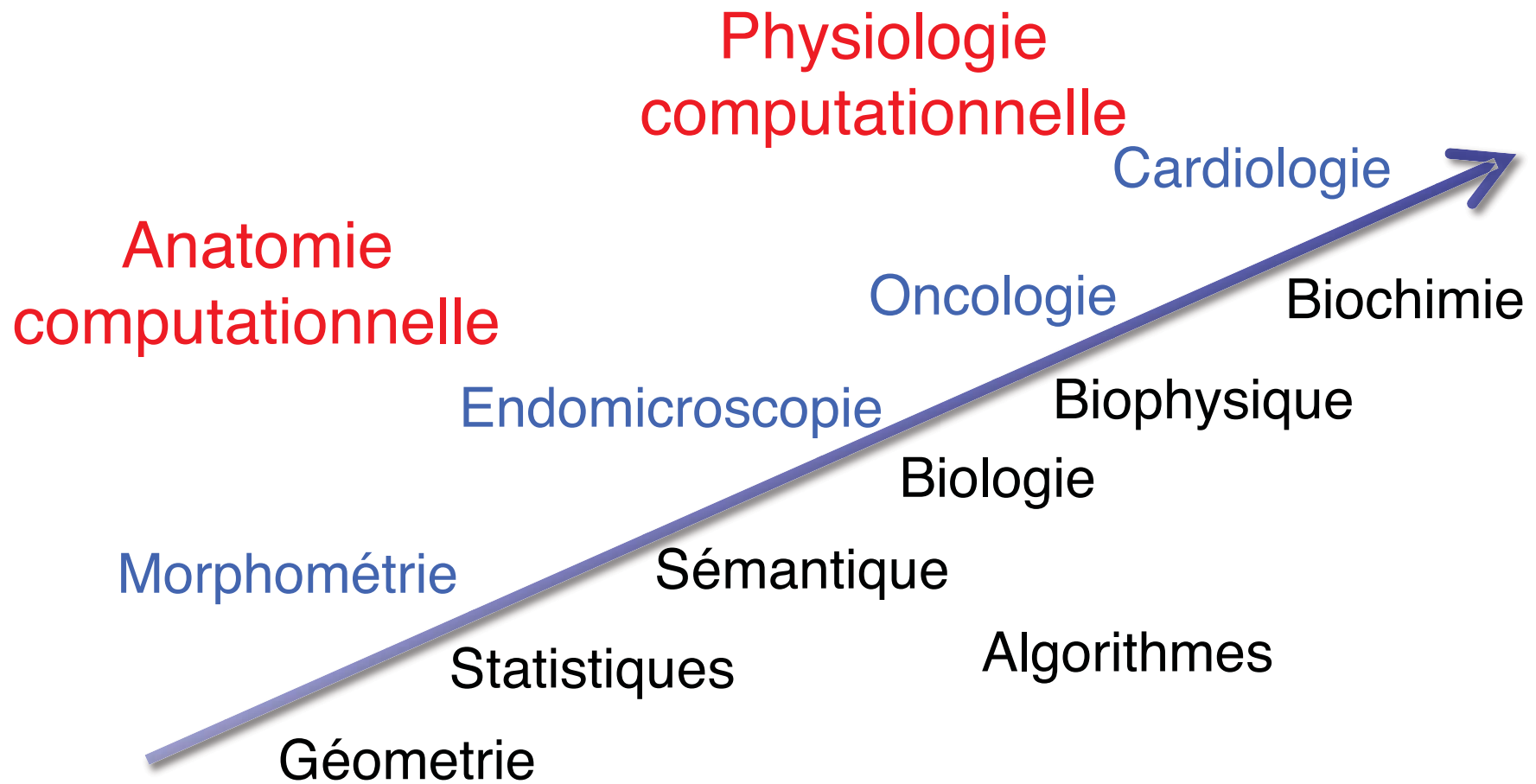


# Science des images médicales

## *Méthodes et algorithmes*

Nikos Paragios, Duncan, Ayache  
Handbook of Medical Imaging, 2014



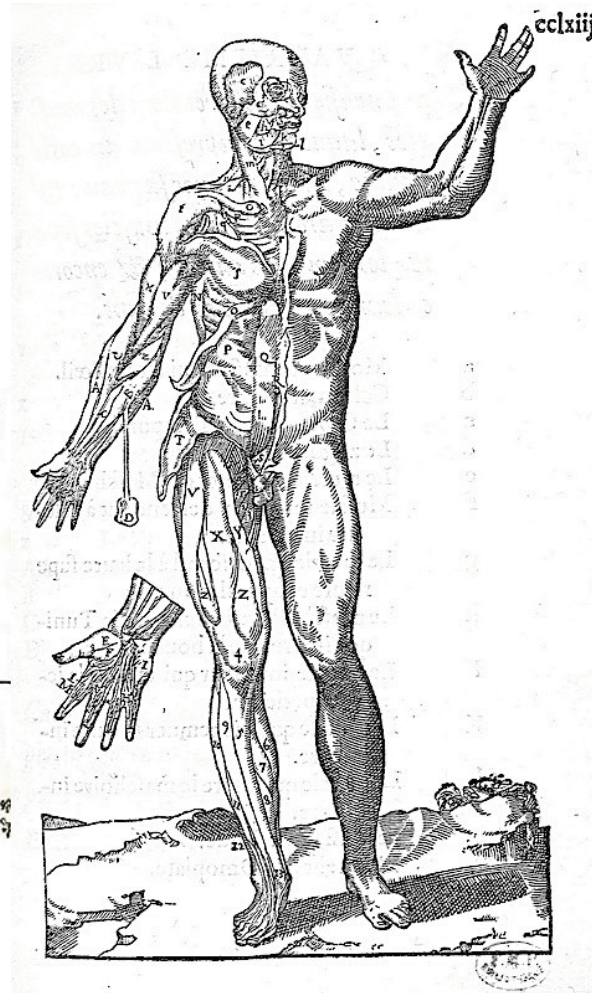


# Anatomie

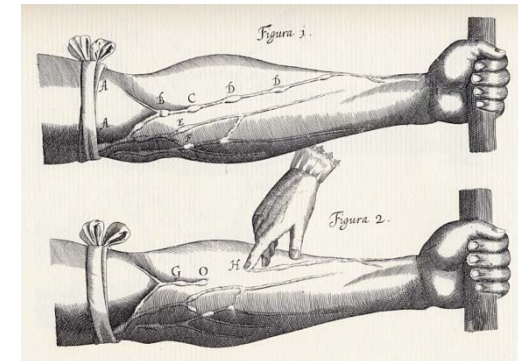
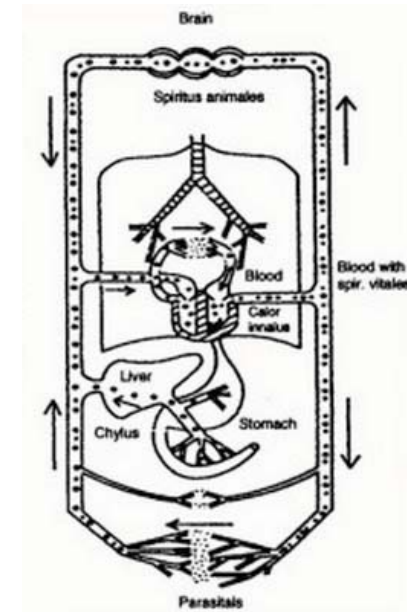
ANDREAS VESALII BRUXELLENSIS  
 HVMANI COR-  
 TERIS QVAS SV-  
 LIBERORVM, SVAQVE  
 LATERE DELINEATIO.  
 PORIS OSSIVM CAE-  
 STINENT PARTIBVS  
 E SEDE POSITORVM EX



**André Vésale,  
1514-1564**



**Ambroise Paré  
1509-1590**



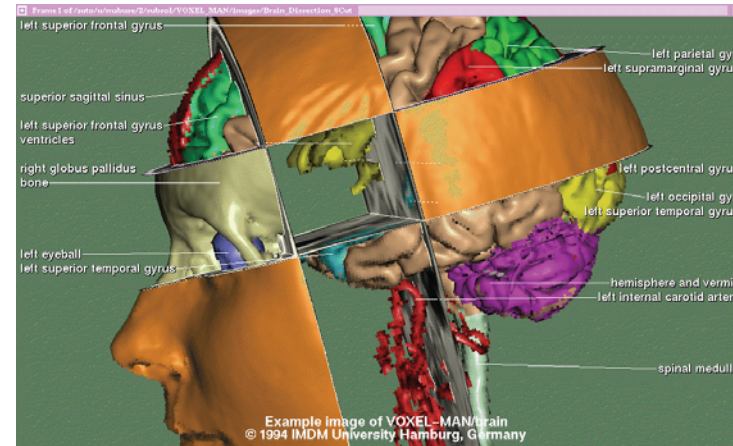
**William Harvey  
1578 – 1657**

# Visible Human, 1989 - 2000

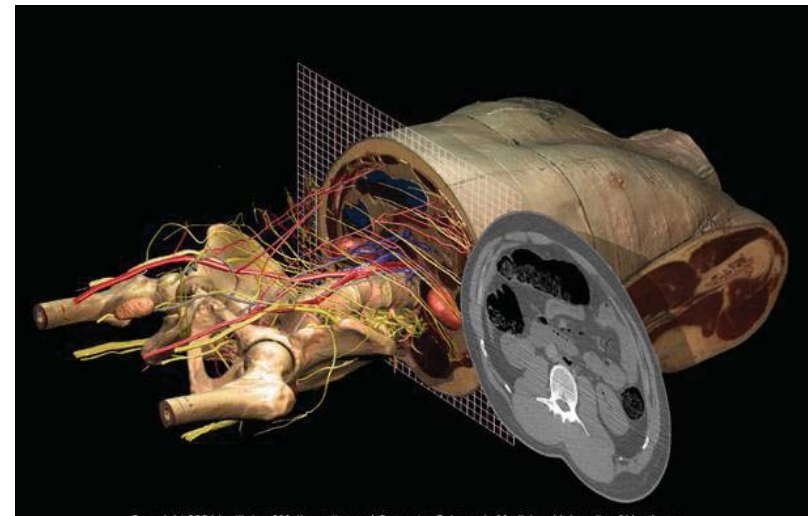
National Library of Medicine, USA



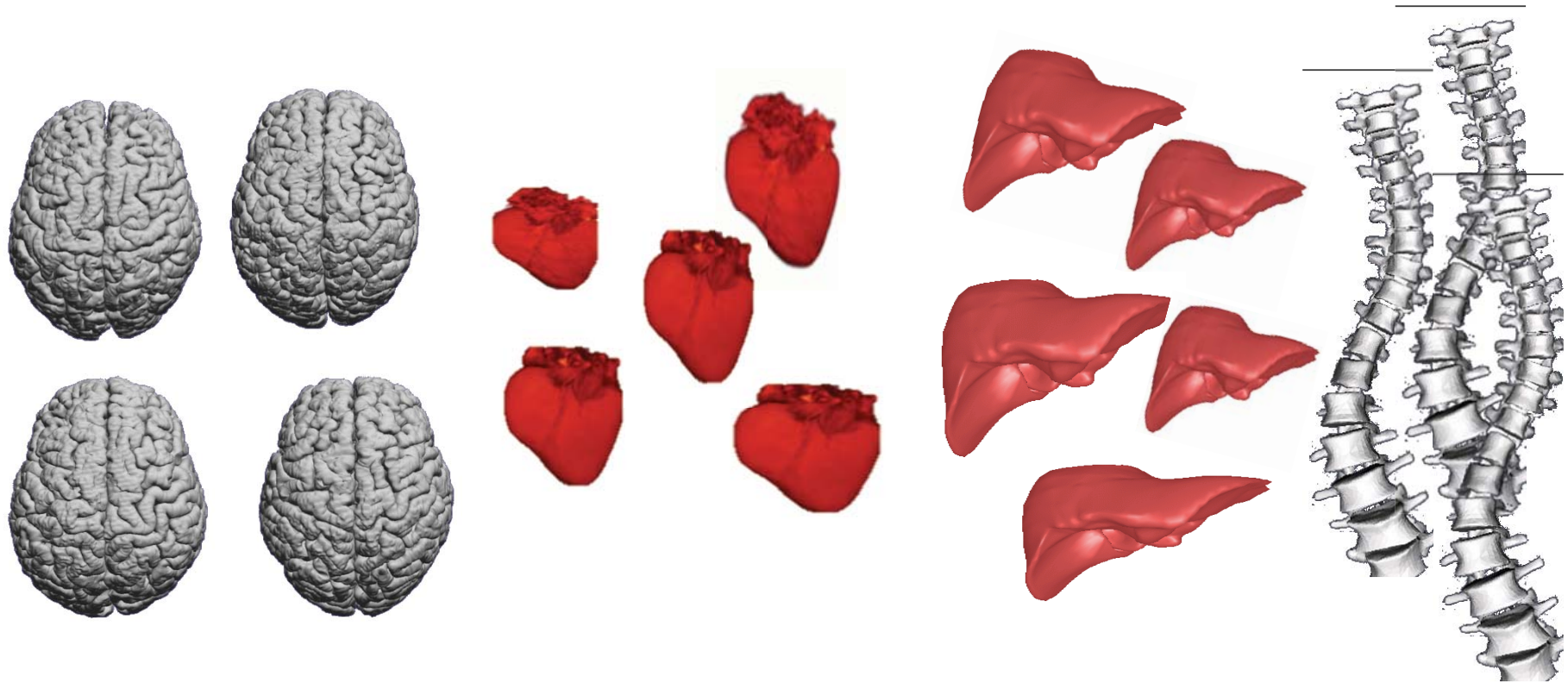
un homme et une femme...



Voxel-Man, U. Hambourg, 2001



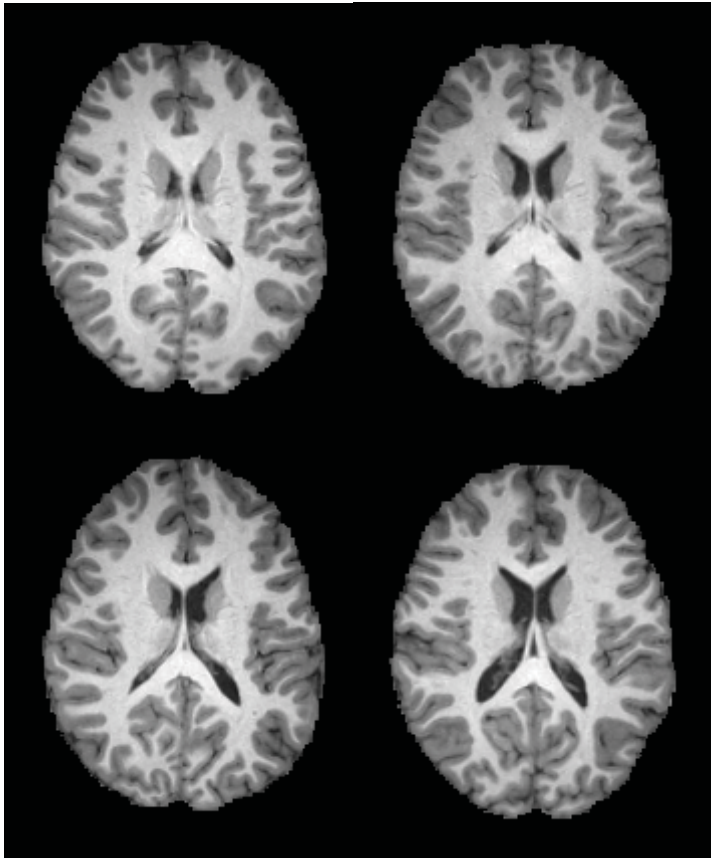
# Anatomie computationnelle



## Modéliser la *variabilité* de l'anatomie humaine

Grenander & Miller 1998: Computational Anatomy, an emerging discipline (Quart. Appl. Math.)  
Pennec and Joshi 2006, *Math. Foundations of Computational Anatomy*, (MICCAI'2006,08,11,13).

# Apparence et forme



# Formes et déformations

D'Arcy Thompson

1917

transformations géométriques

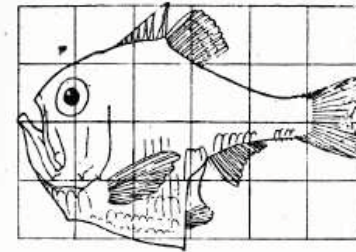
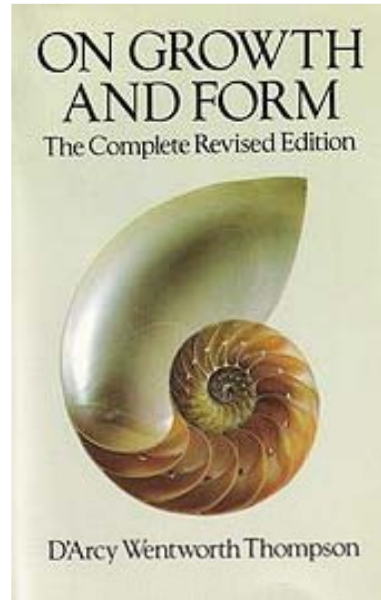


Fig. 517. *Argyropelecus Olfersi*.

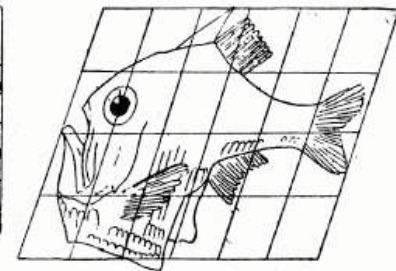
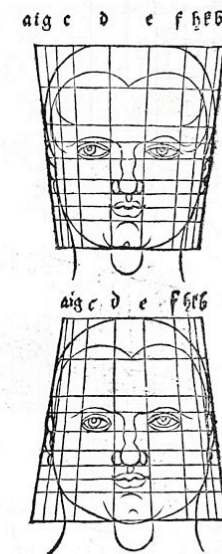
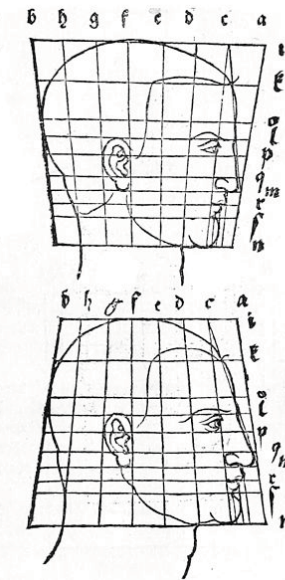
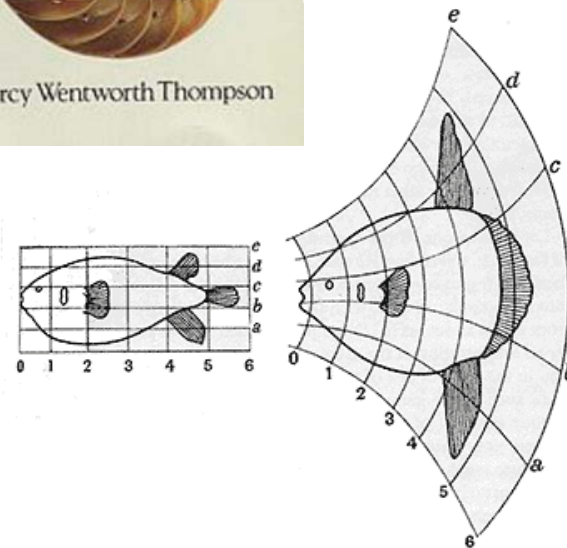


Fig. 518. *Sternoptyx diaphana*.

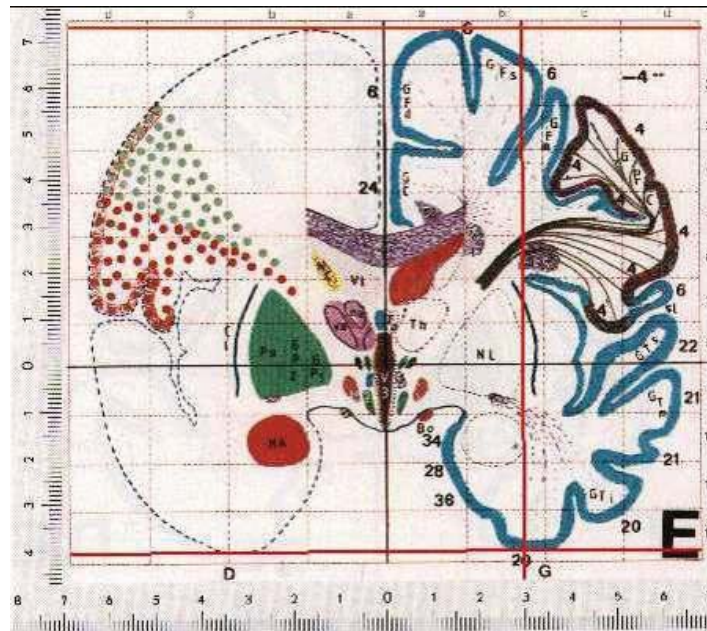


# Atlas cérébral



Talairach et Tournoux, 1988

Introduit dès 1957

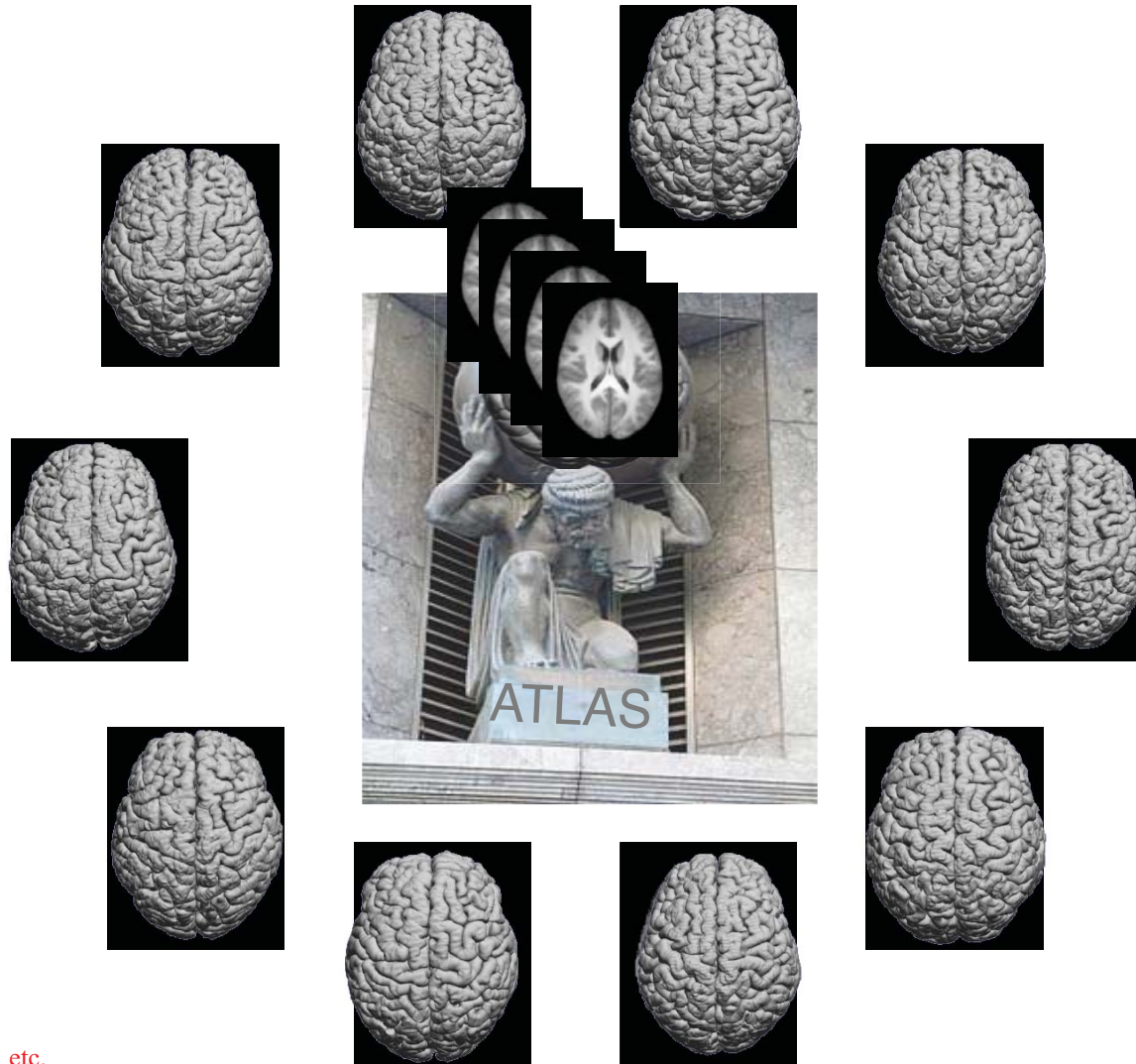


Avec un algorithme  
de recalage linéaire  
par morceaux





# Anatomie moyenne



Bookstein,  
Guimond et al.  
Faugeras et al.,  
Miller et al.,  
Trouvé, Younes, Allassonière, etc.

# Variétés géométriques



- Formes et déformations ne sont en général pas représentées dans des espaces vectoriels
- **Moyenne** et covariance doivent être redéfinies

# Géométrie riemannienne

- **App. exponentielle :**
  - espace tangent  $\rightarrow$  variété
- **App. logarithmique**
  - variété  $\rightarrow$  espace tangent

- Distance géodésique

$$d(x, y) = \inf L(\gamma)$$

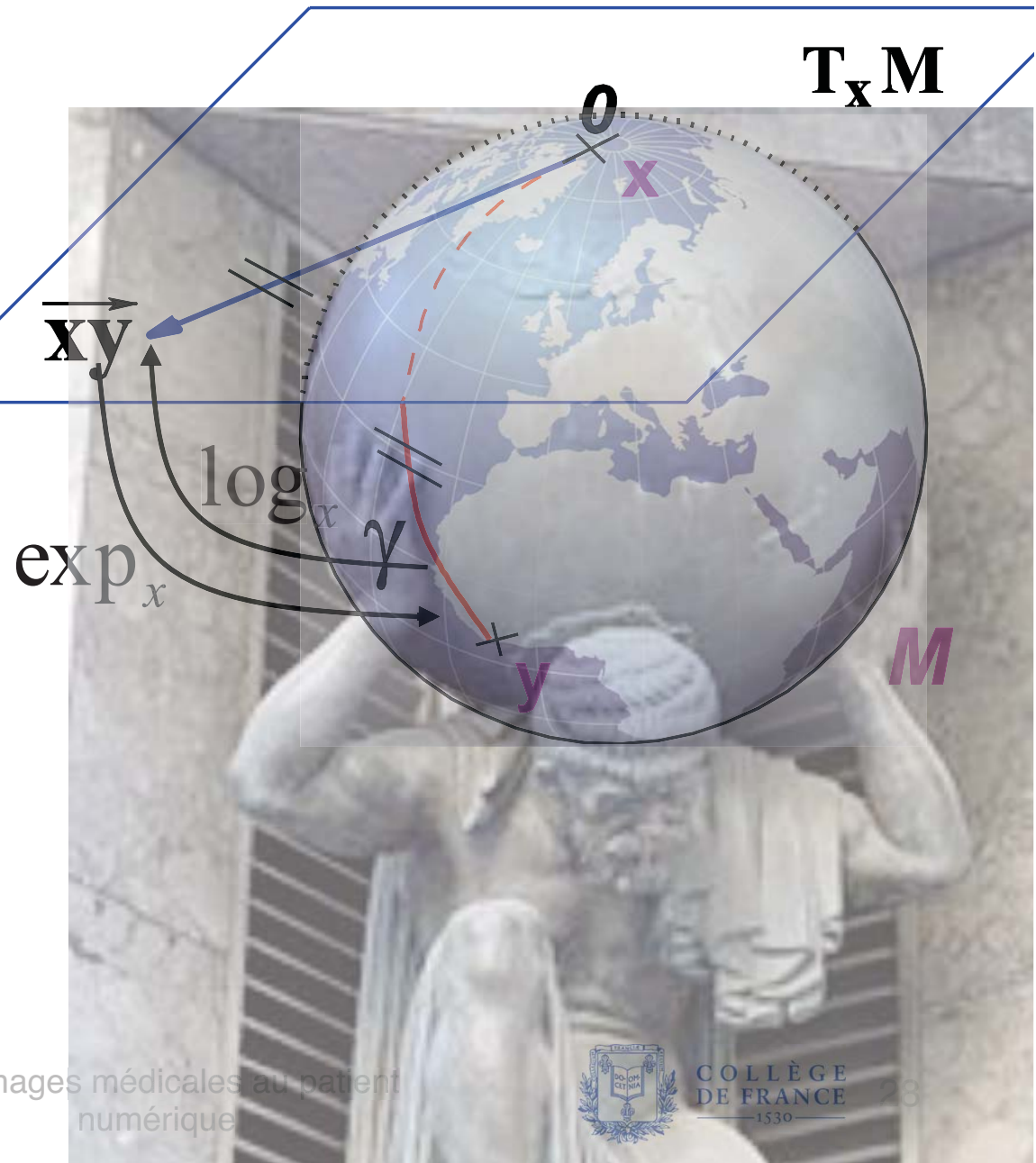
- Espérance de Fréchet

$$\mu = \arg \min_{x \in M} \sum_{i=1}^N d(x, x_i)^2$$

X. Pennec et al.

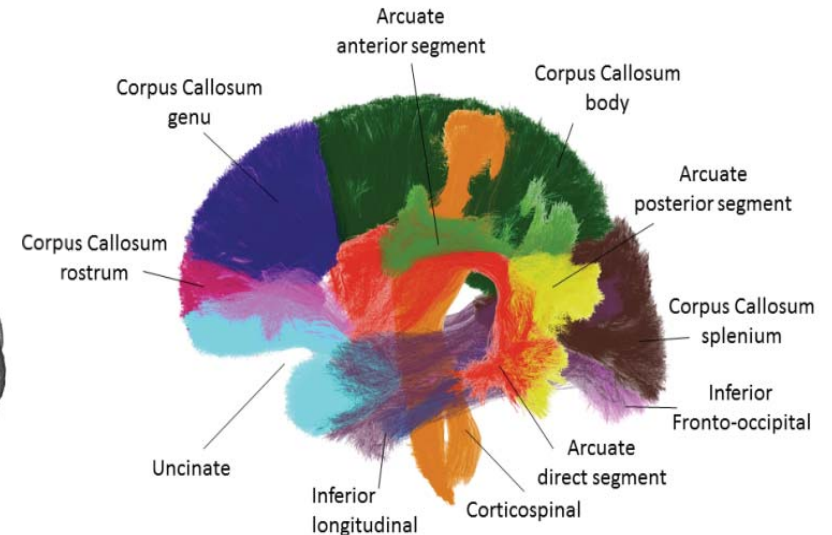
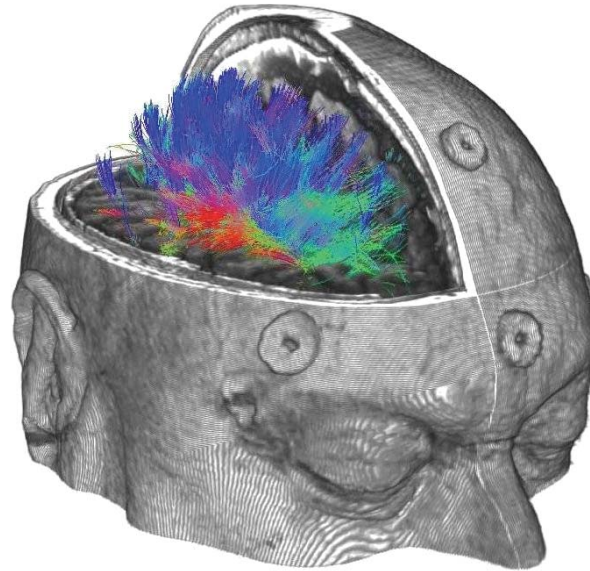
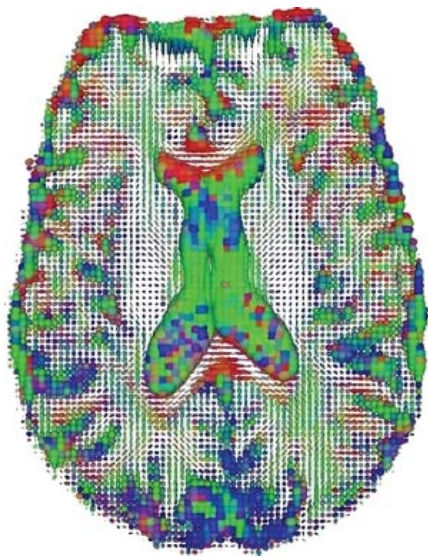
Nicholas Ayache  
10 avril 2014

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# Tenseurs de diffusion



## Connectivité

J.F. Mangin, C. Poupon et al.,  
Neurospin

- Métriques riemanniennes

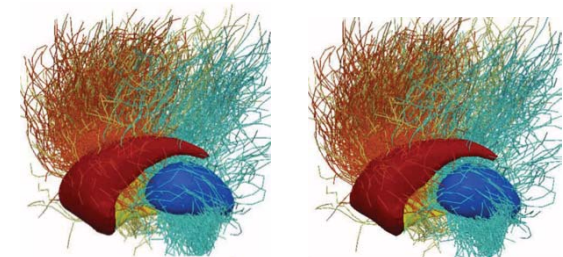
### Affine-invariante

$$dist(\Sigma, \Psi)^2 = \left\langle \overline{\Sigma\Psi} \mid \overline{\Sigma\Psi} \right\rangle_{\Sigma} = \left\| \log(\Sigma^{-1/2} \cdot \Psi \cdot \Sigma^{-1/2}) \right\|_{L_2}^2$$

### Log-euclidienne

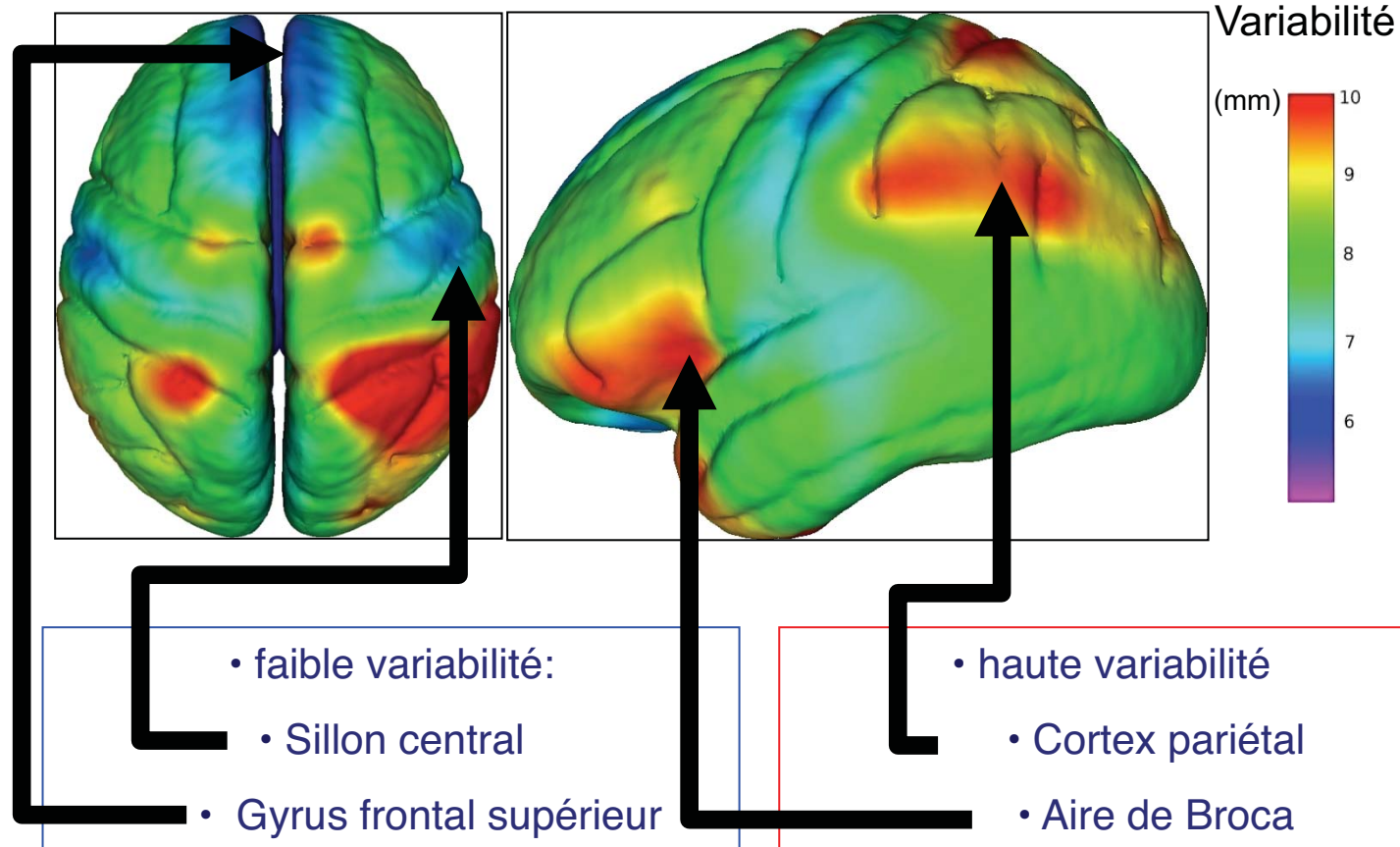
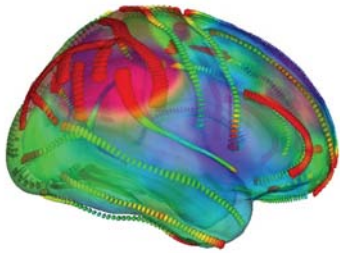
$$dist(\Sigma, \Psi)^2 = \left\| \log(\Sigma) - \log(\Psi) \right\|^2$$

V. Arsigny, P. Batchelor, C. Lenglet, R. Deriche, X. Pennec, T. Fletcher, etc.



P. Gori, O. Colliot et al., Miccai 2013

# Atlas morphologique du cortex



P. Fillard, et al., Neuroimage 2007

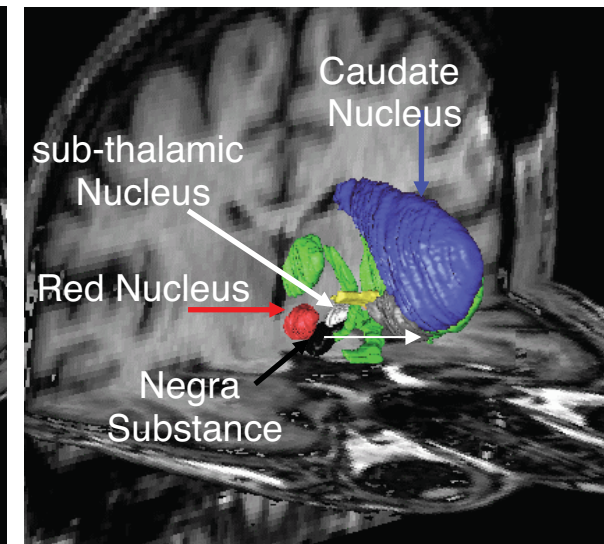
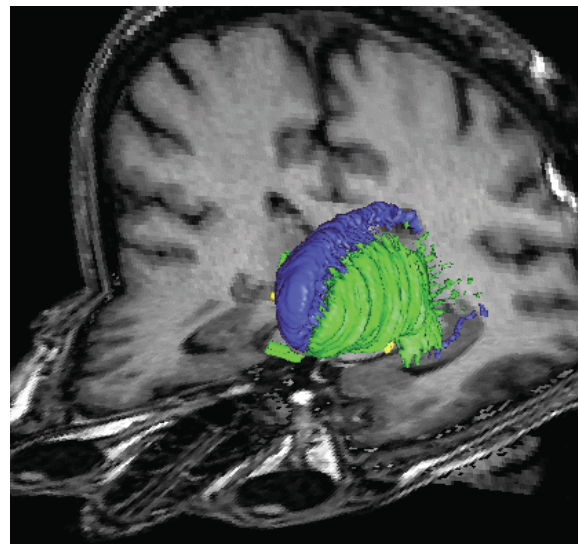
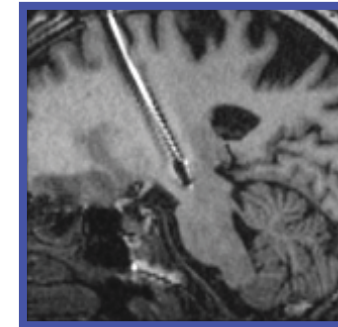
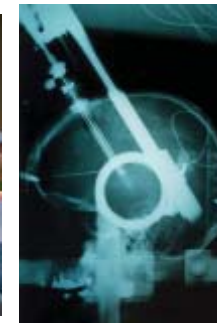
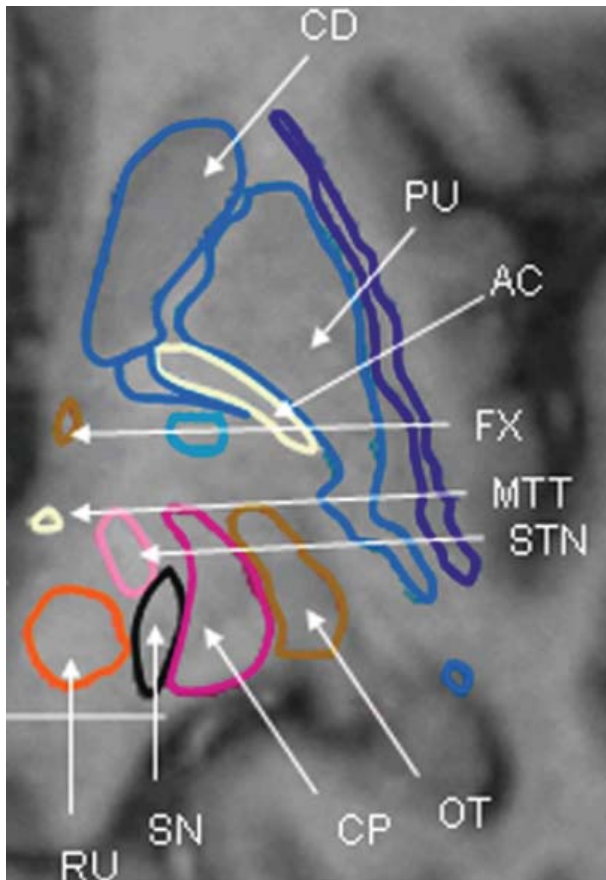
P. Thompson, UCLA

LONI

# Atlas pour la neurochirurgie

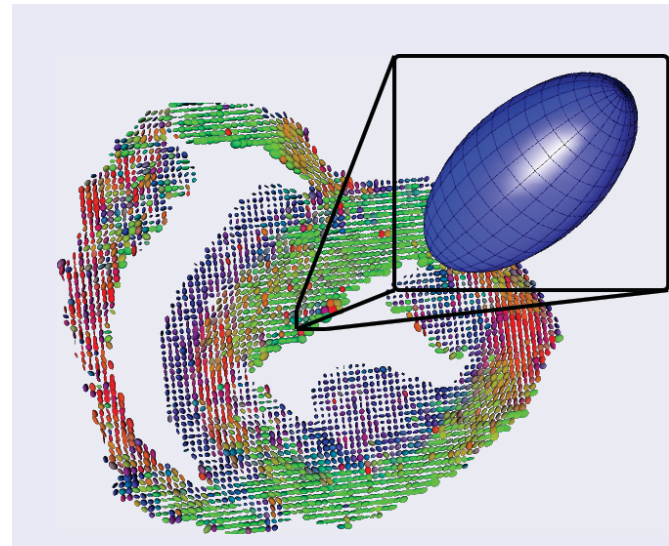
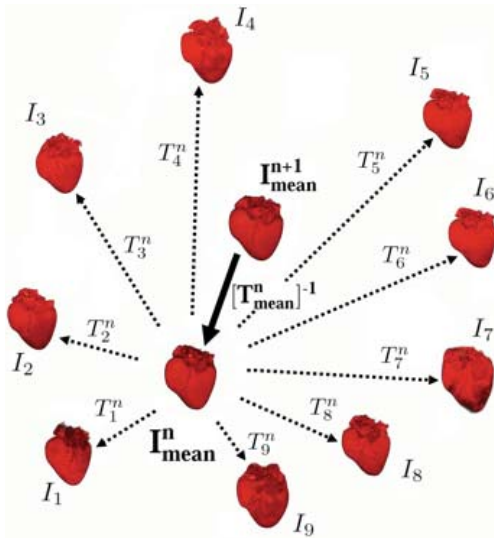
- Electrostimulation de patients parkinsoniens

IHU Pitié Salpêtrière

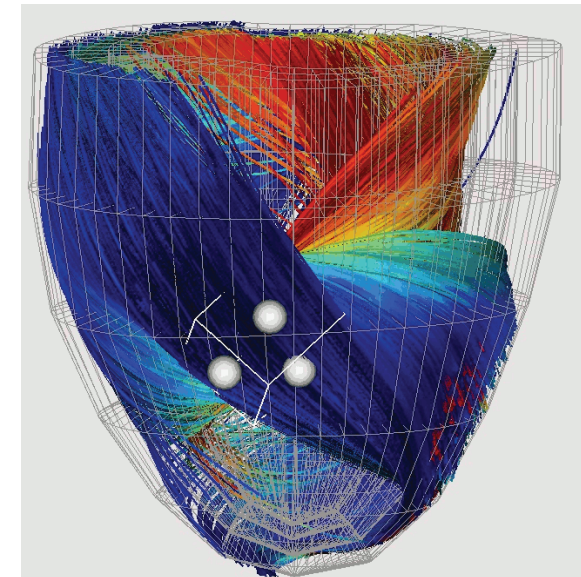


J Yelnik, E Bardinet, D Dormont, G Malandain, S Ourselin, D Tande, C Karachi, N Ayache, P Cornu, Y Agid. *Neuroimage*, 2007

# Atlas cardiaque



Creatis



KING'S  
College  
LONDON

H Lombaert, JM Peyrat, P Croisille, , F Chriet, P Clarysse, I Magnin et al, IEEE Tr. on Medical Imaging 2012.

N. Toussaint, et al, *Medical Image Analysis* 2013.

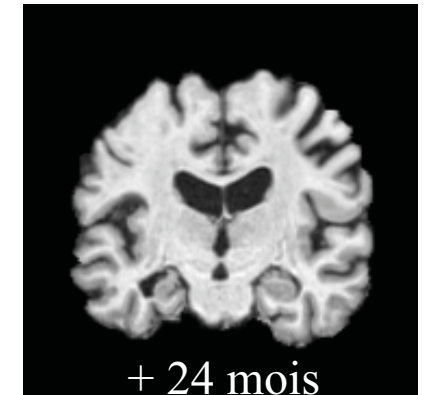
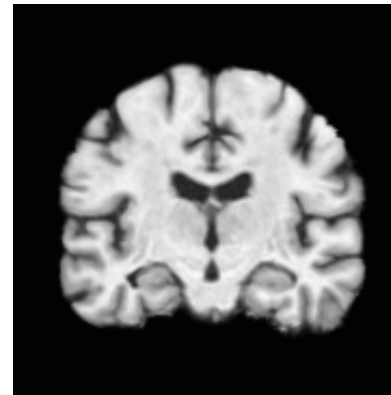
# Morphométrie dynamique

- *Evolution temporelle* de formes 3D



# Maladie d'Alzheimer

- Enjeu de santé publique
- Prévalence pays développés
  - Age 65-70: 2%
  - Age 70-80: 4%
  - Age 80 - : 20%



- Mesurer l'efficacité de nouveaux médicaments, les tester précocement.

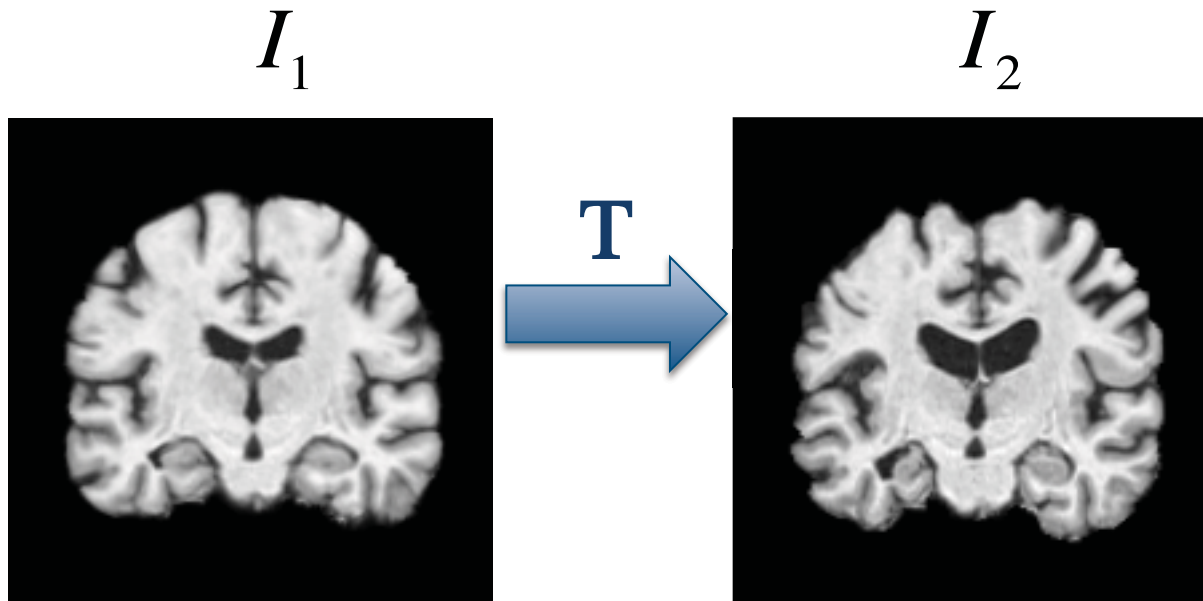
*ADNI*  
*CATI*

P. Thompson., N. Fox, G. Frisoni et al.

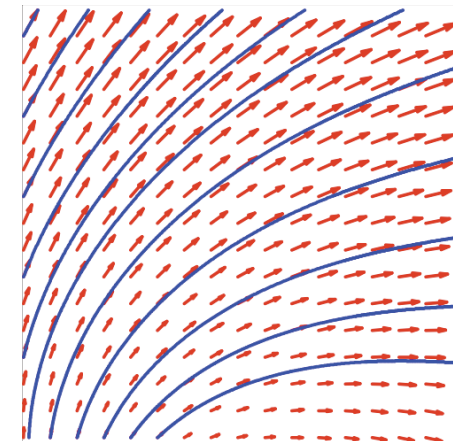
B. Dubois et al., Lancet Neurol. 2010

O. Colliot et al., Académie de médecine, 2013

# Recalage d'images



Difféomorphisme



$v$  : champ de vitesses

$$E = d(T(I_1), I_2)^2 + R(T)$$

$T = \exp(t.v)$  = sous-groupe à 1 paramètre

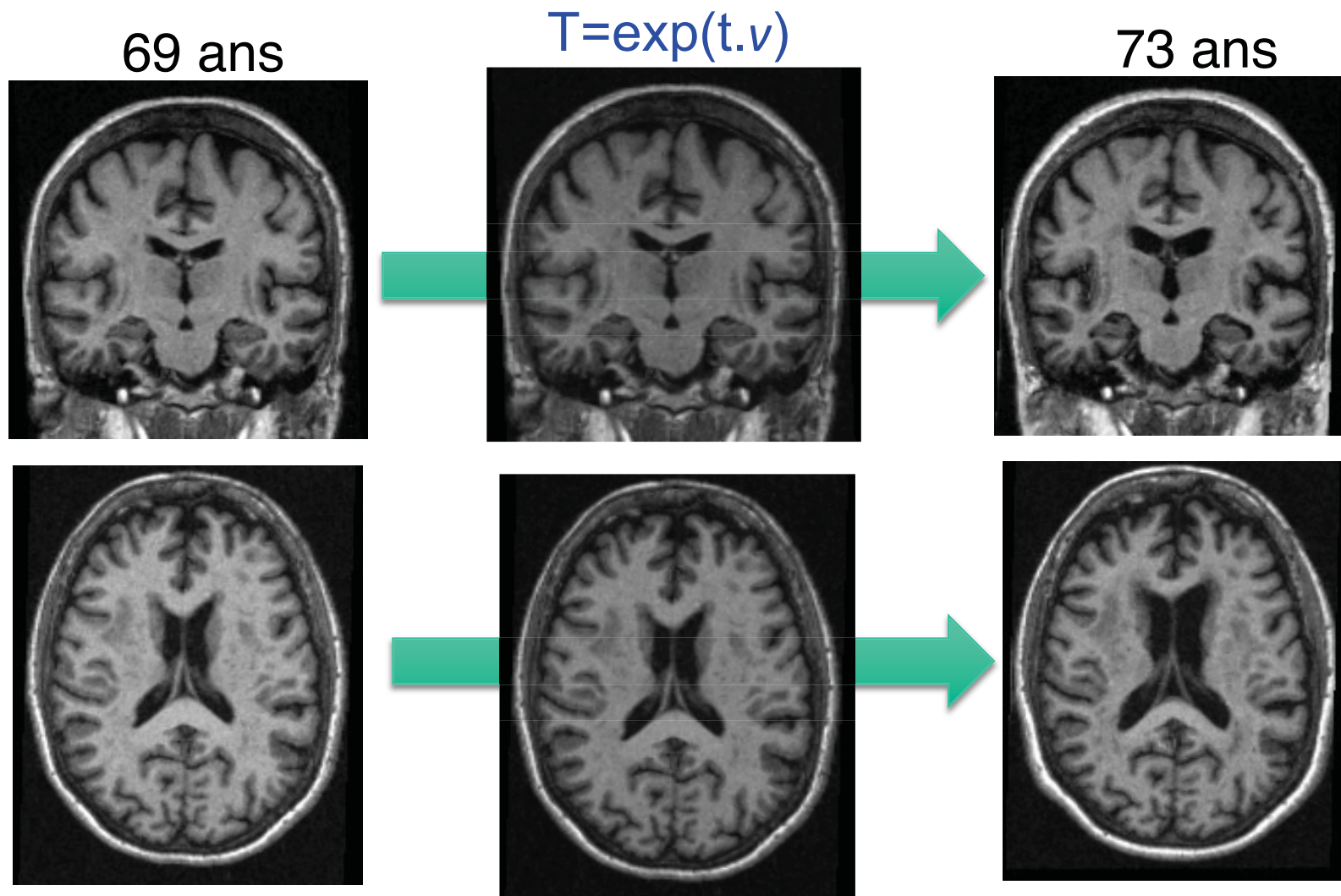
Algorithme des démons  
difféomorphes

Lorenzi et al., Neuroimage 2013

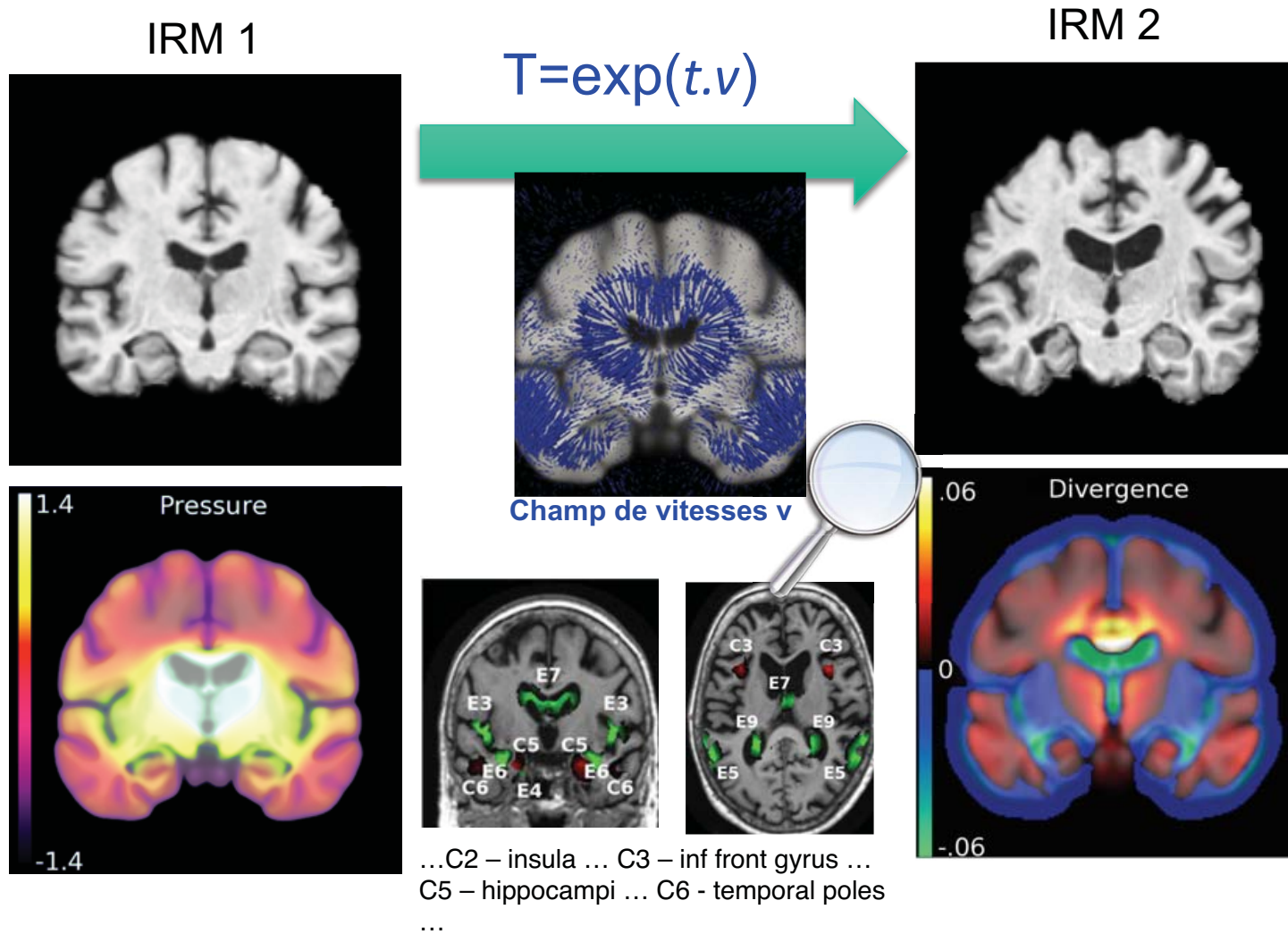
$$\begin{cases} \frac{\partial \phi(x, t)}{\partial t} = v(\phi(x, t)) \\ \phi(x, 0) = id \end{cases}$$

A. Trouvé, L. Younes, et al.

# Analyse longitudinale



# Quantification de l'atrophie

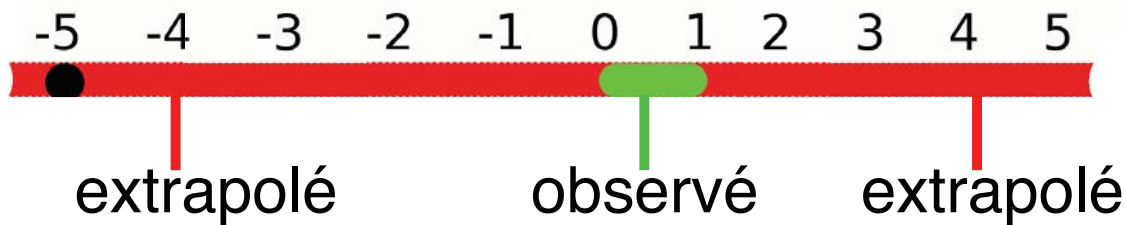
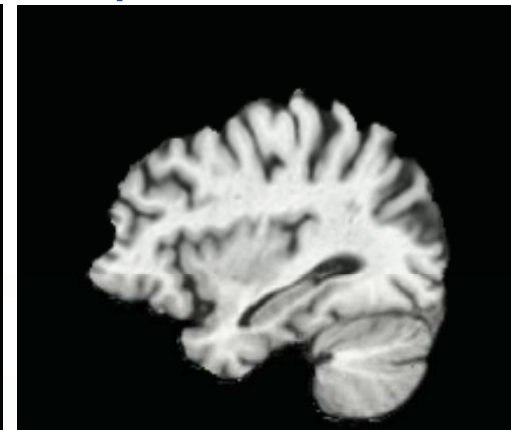
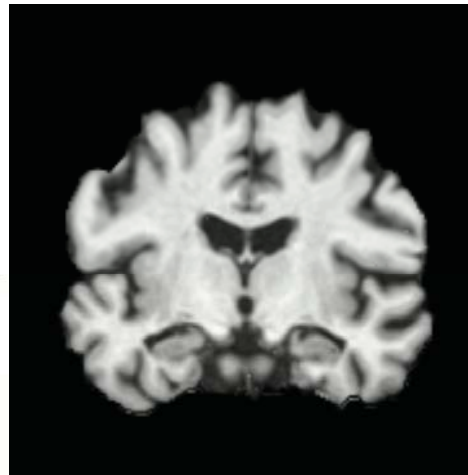
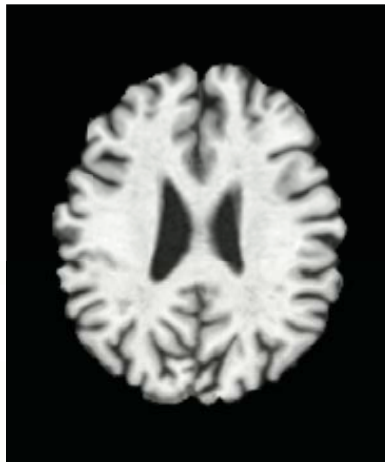


*M Lorenzi et al. MICCAI 2012*

# Modèle moyen d'atrophie

$$\bar{\phi} = \exp(t\bar{v})$$

70 patients, ADNI

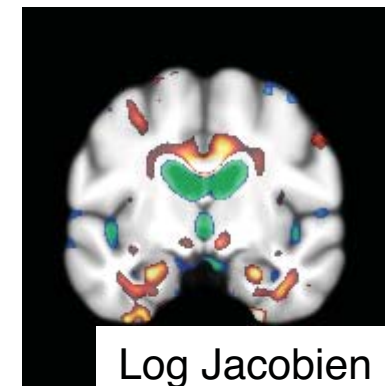
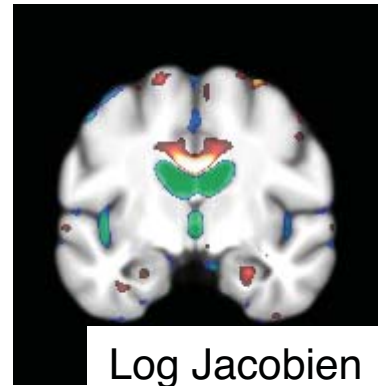


# Comparer 2 groupes

3 ans

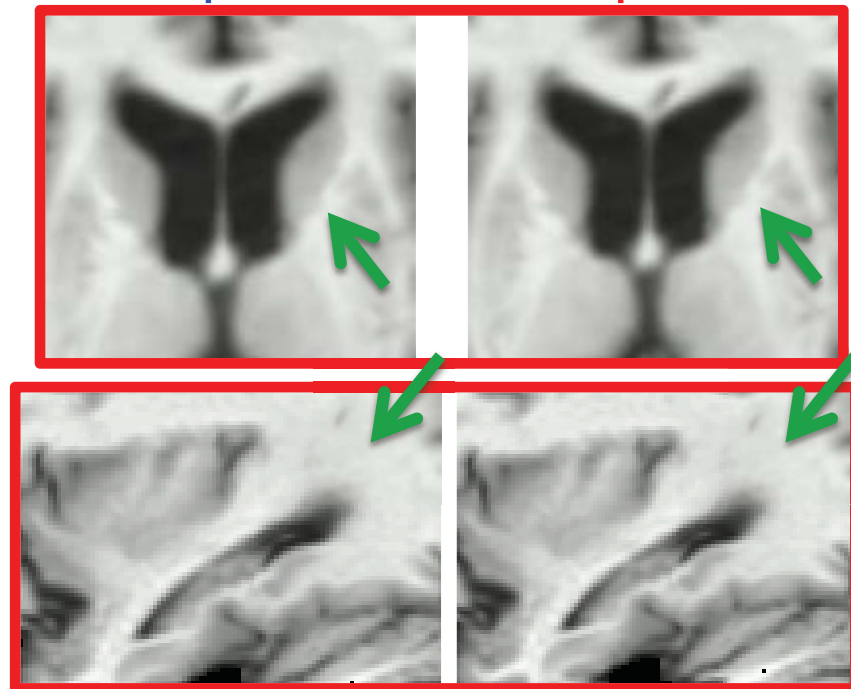
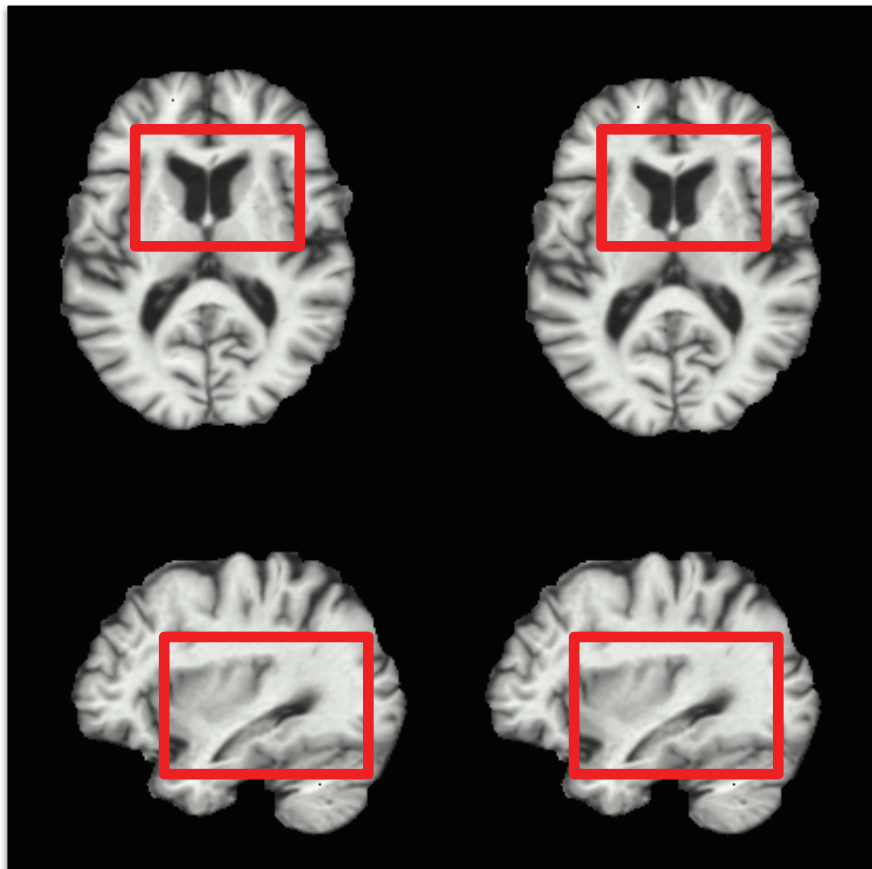
57 participants  
 $A\beta 1-42-$

41 participants  
 $A\beta 1-42+$



$A\beta 1-42-$

$A\beta 1-42+$

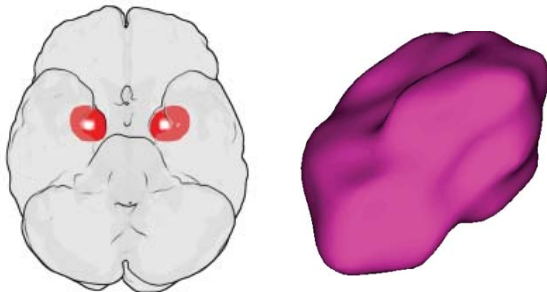


# Développement du cerveau chez l'enfant

Source: D. Rueckert, ICL

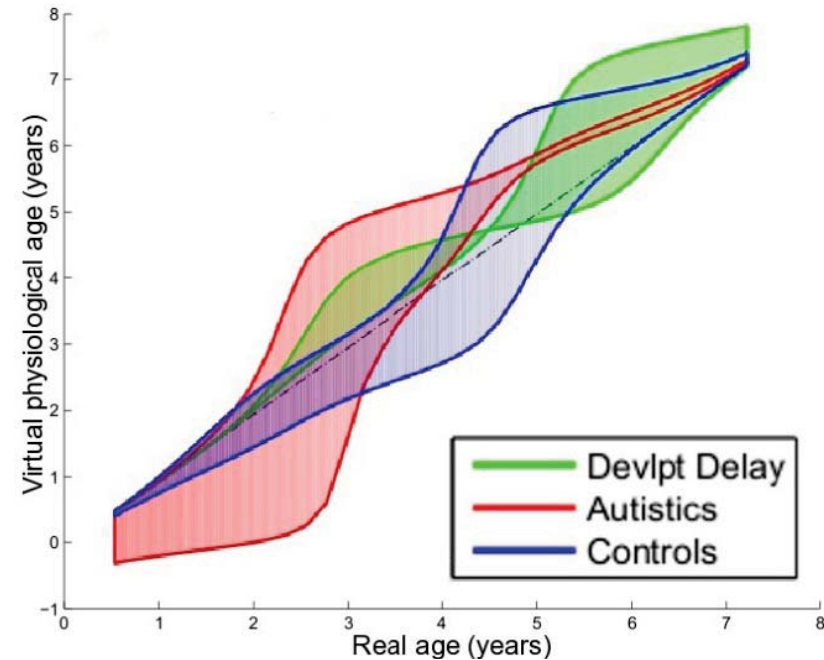


Durrleman, Gerig et al.



Amygdales cérébrales

Avec SCI Institute, Utah



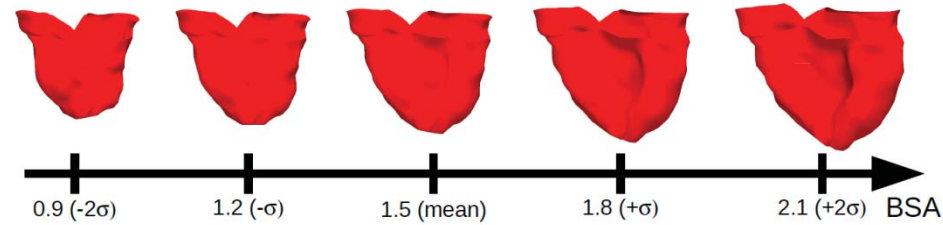
$$J(\phi, \psi) = \sum_{t_j} d(\phi(S(\psi(t_j))), T_{t_j})^2 + \gamma_\phi \text{Reg}(\phi) + \gamma_\psi \text{Reg}(\psi)$$

S Durrleman et al., *Int. J. of Computer Vision* 2012.

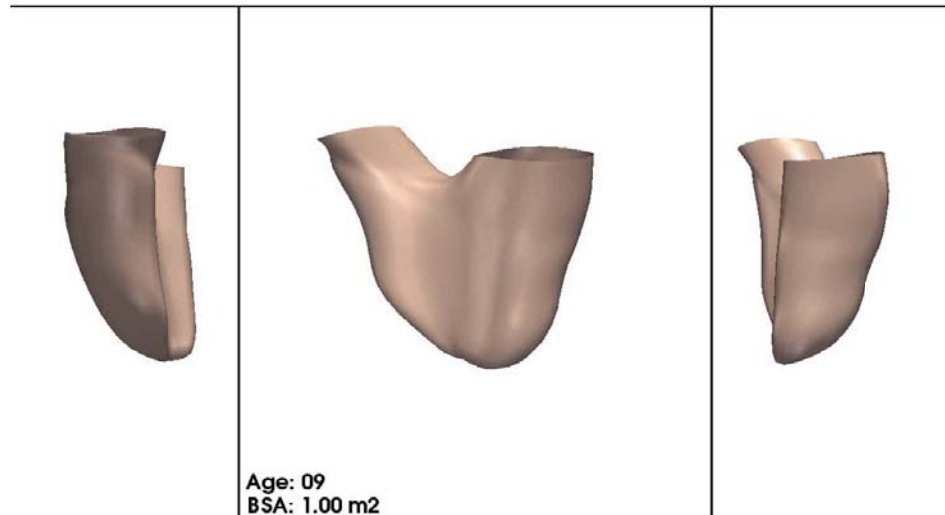
Courants  
mathématiques

# Cardiologie pédiatrique

49 enfants à  
différents âges  
avec une  
tétralogie de  
Fallot



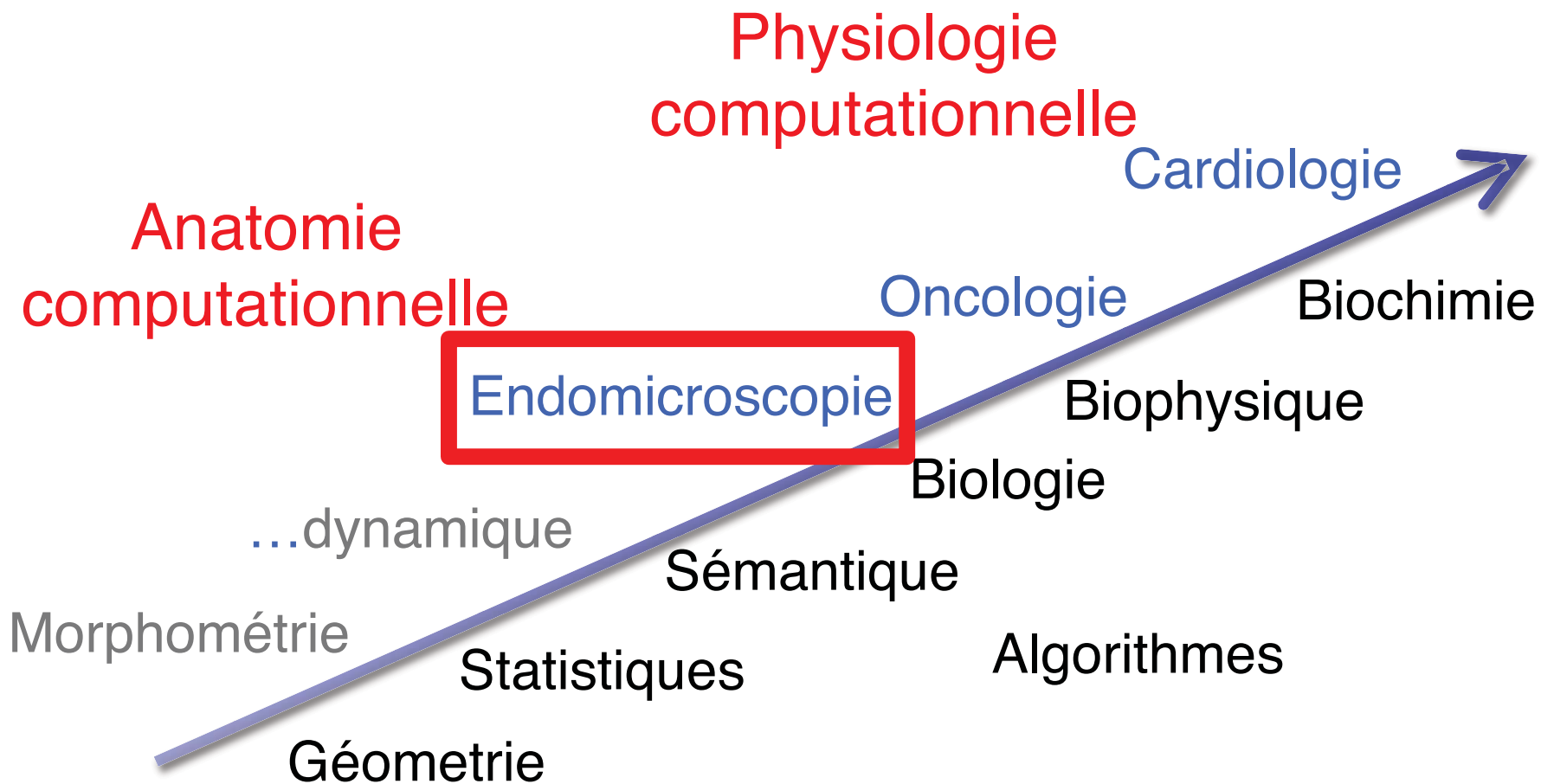
Évolution du  
ventricule droit  
en fonction  
de l'âge



Health-e-Child  
Necker &  
Gosh  
+Siemens

B Leonardi et al. European Heart Journal – CardioVascular Imaging 2013



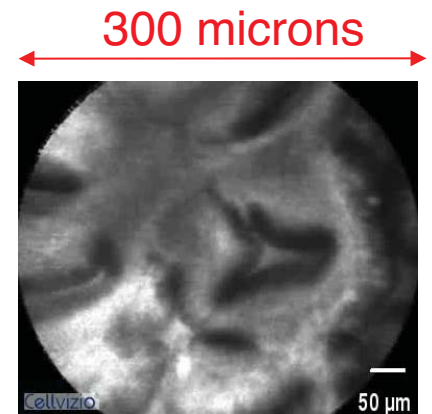


# Endomicroscopie

*pCLE: probe-based Confocal Laser Endomicroscopy*



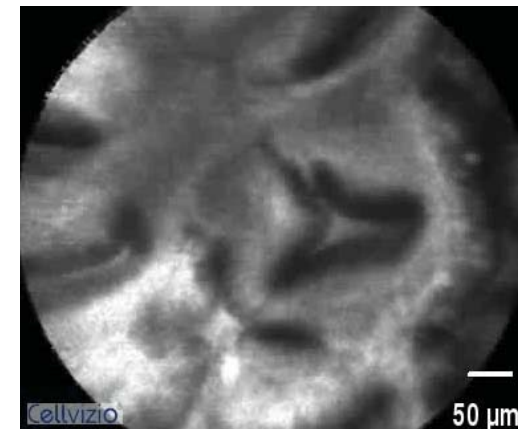
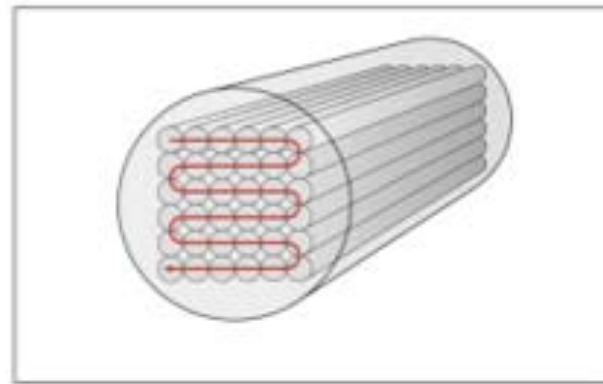
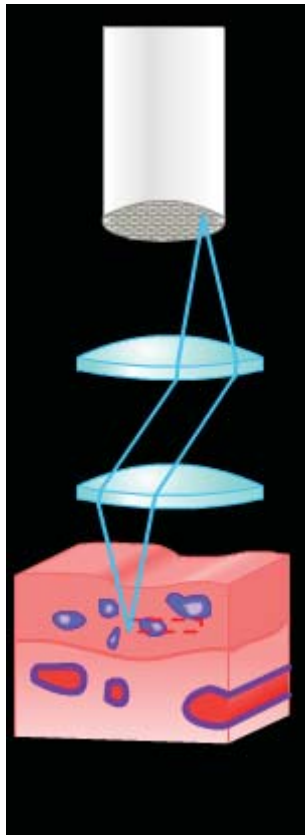
Pr A. Meining, Munich



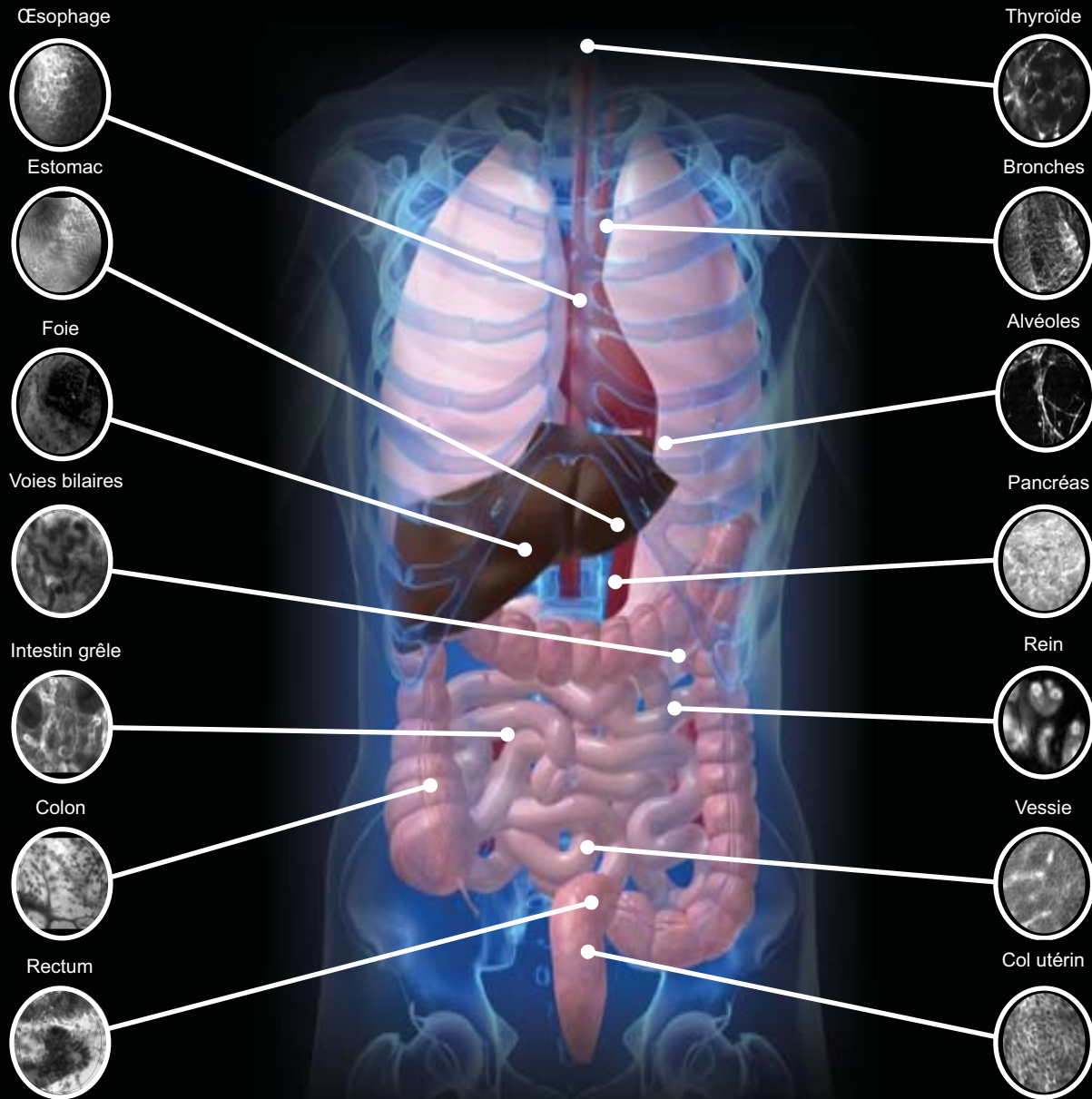
Muqueuse gastro-oesophagienne

Mauna Kea Technologies (MKT) , Paris  
S. Loiseau

# Principes physiques



# Biopsies optiques

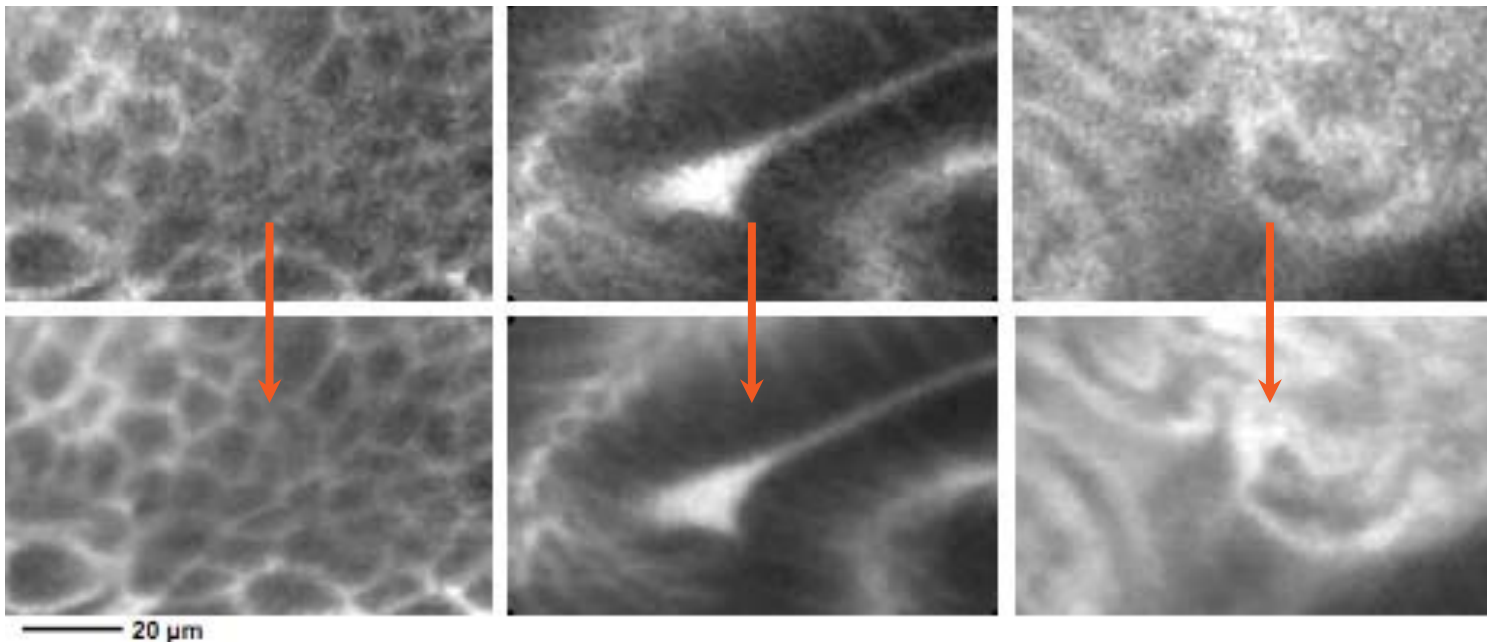
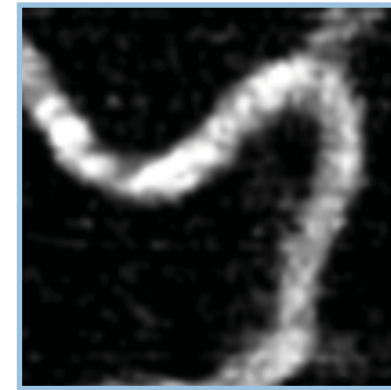
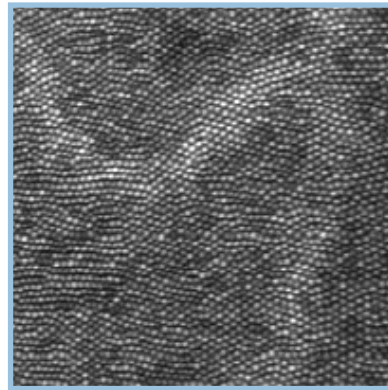


F. Lacombe

# 1. des photons aux pixels

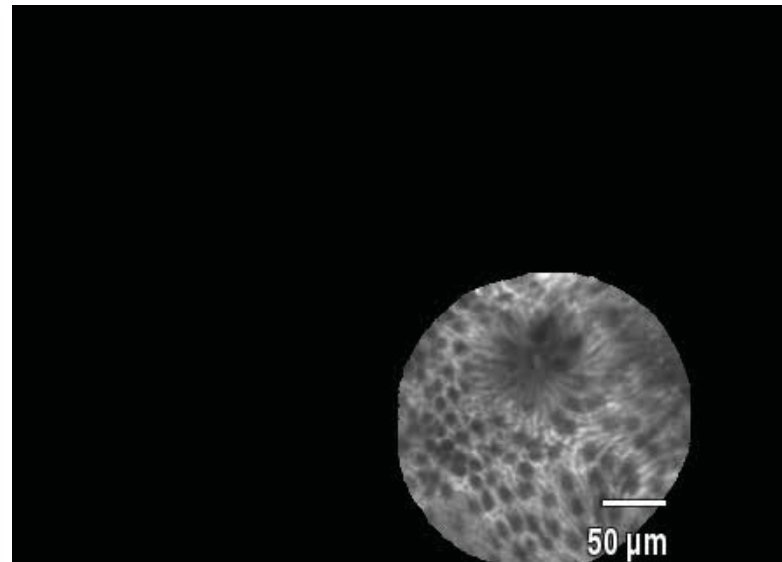
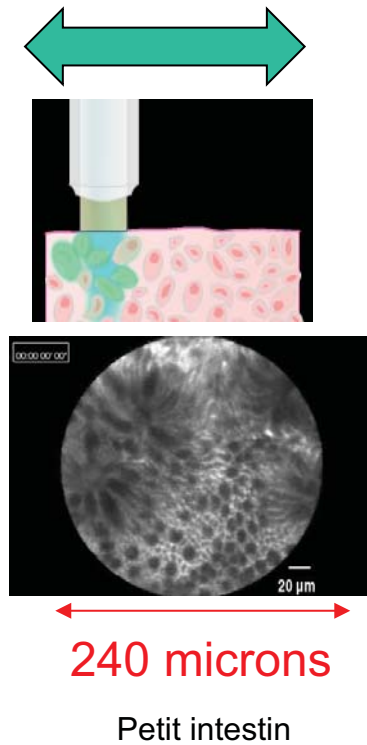
- Corriger

- Mesures éparses
- Distorsions
- Inhomogénéités
- fluctuations



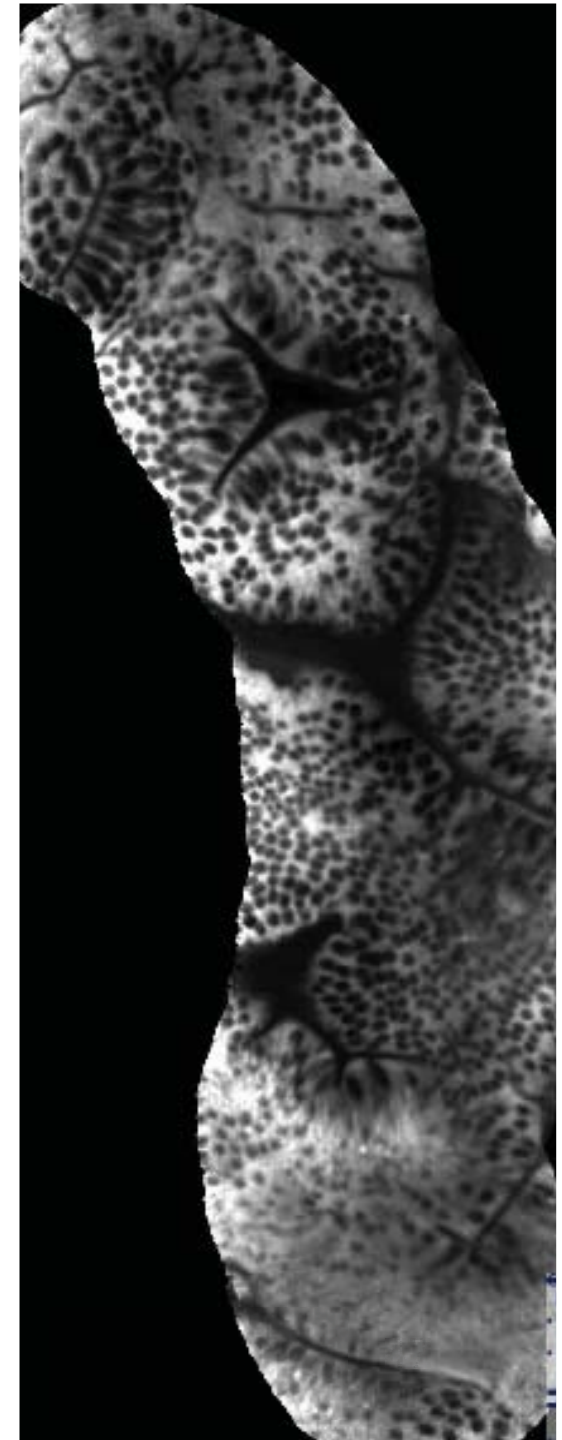
## 2. du micro au mésoscopique

mosaïques numériques



Corriger distorsions dues au  
mouvement et déformations  
des tissus

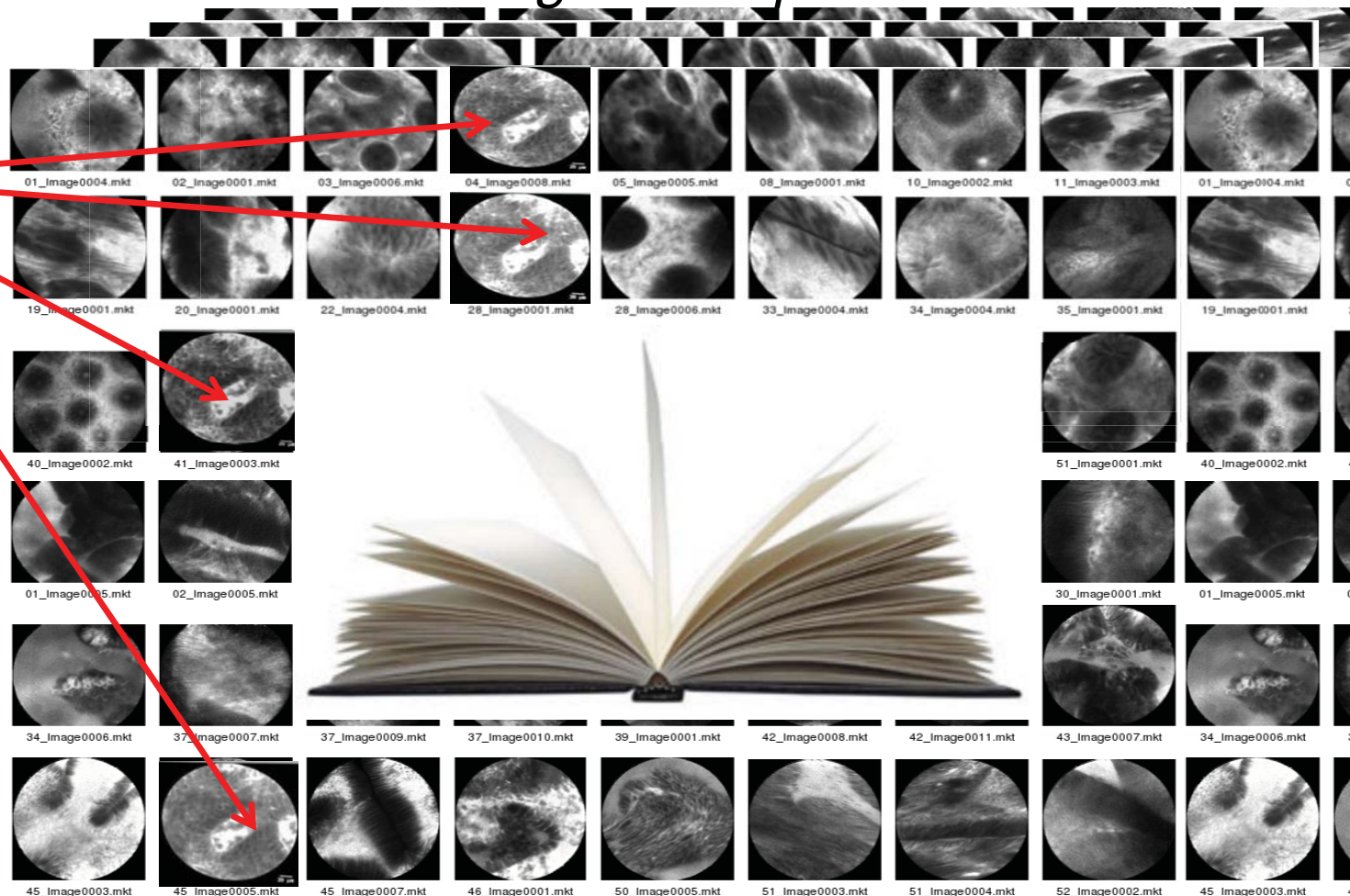
T. Vercauteren et al. 2006.



# 3. Atlas intelligent

## *Images et expertises*

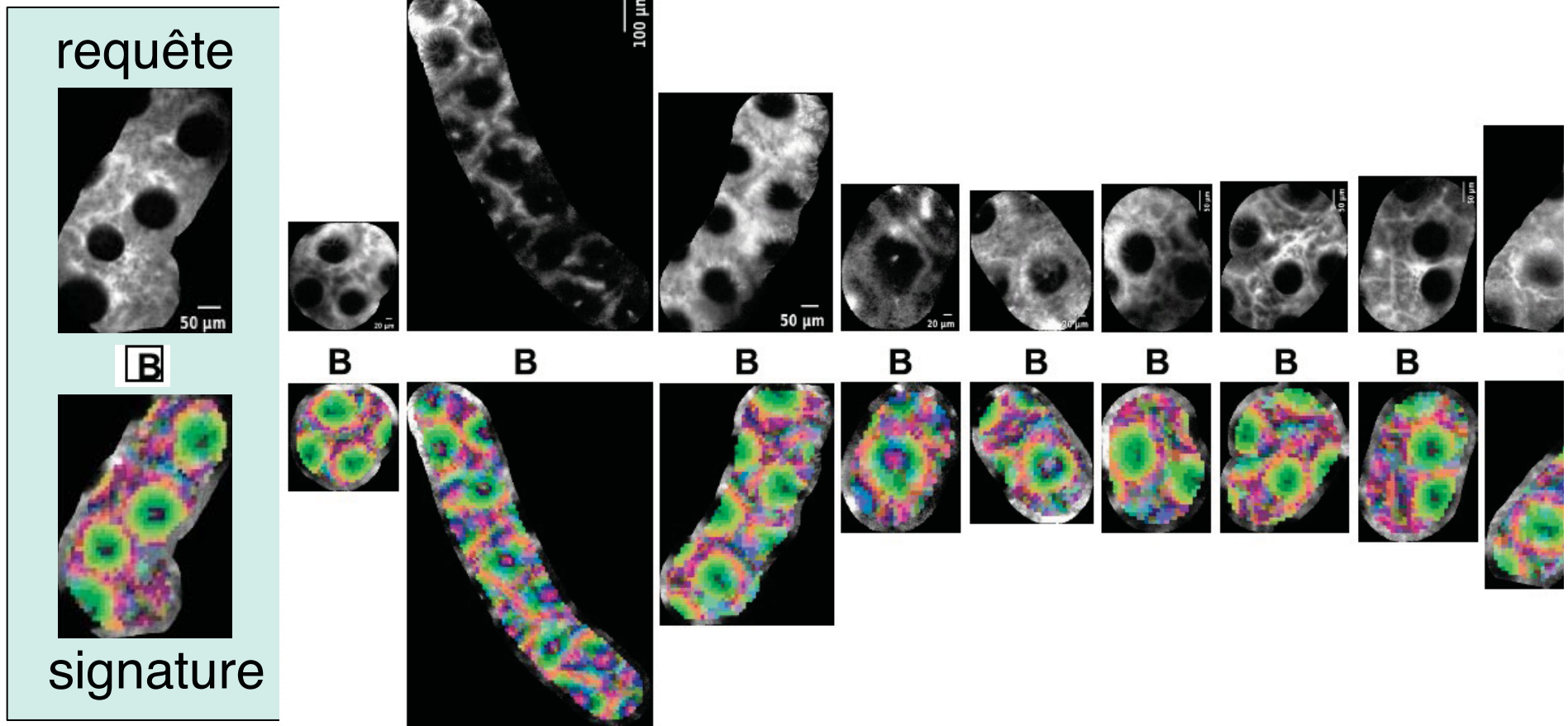
Nouvelle image



B André et al. IEEE TMI 2012

# Signature visuelle

Mots visuels: **Descripteurs locaux** de l'image  
*invariants par rotations, translations, changement affine d'illumination*





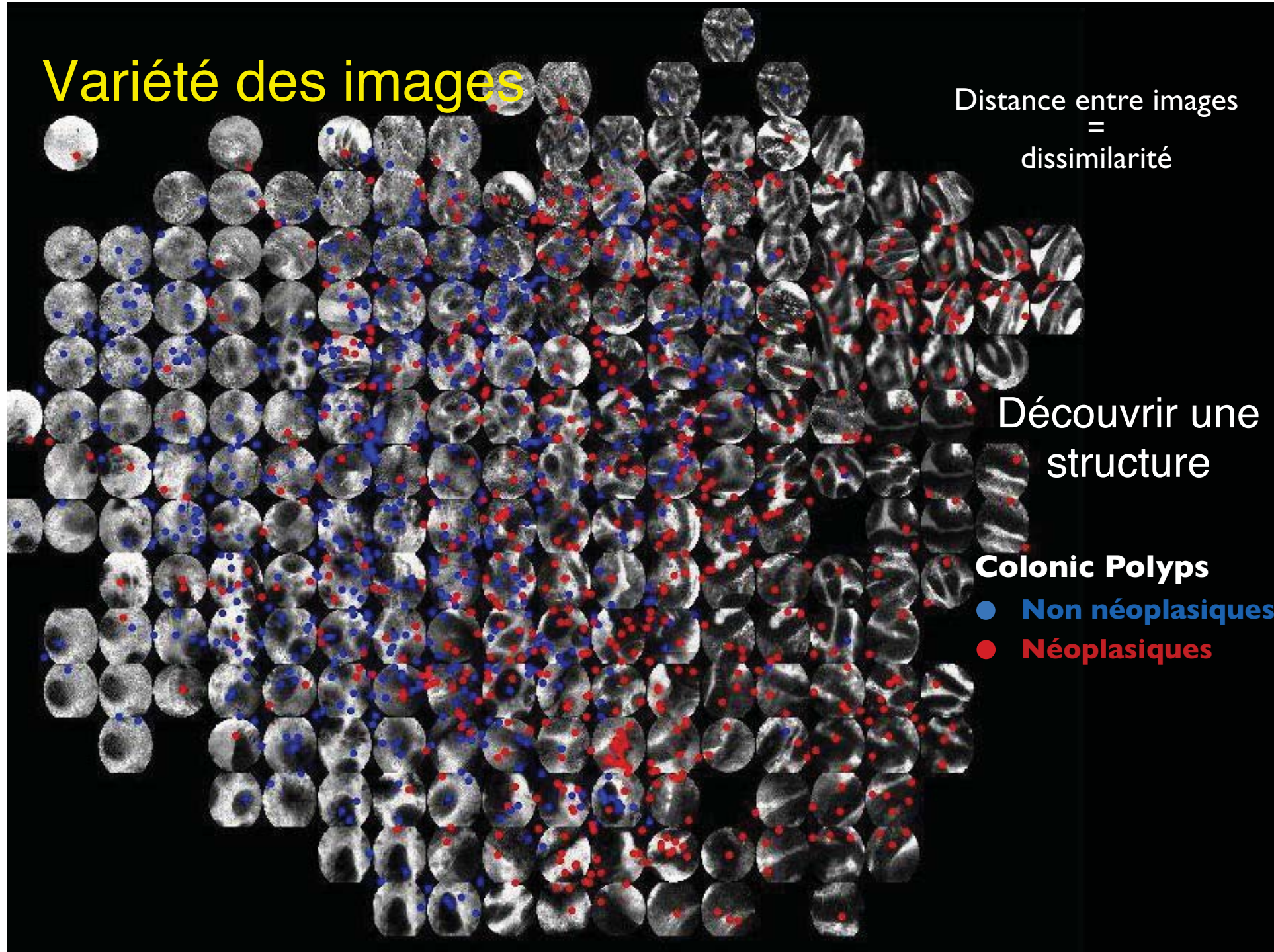
# Variété des images

Distance entre images  
=  
dissimilarité

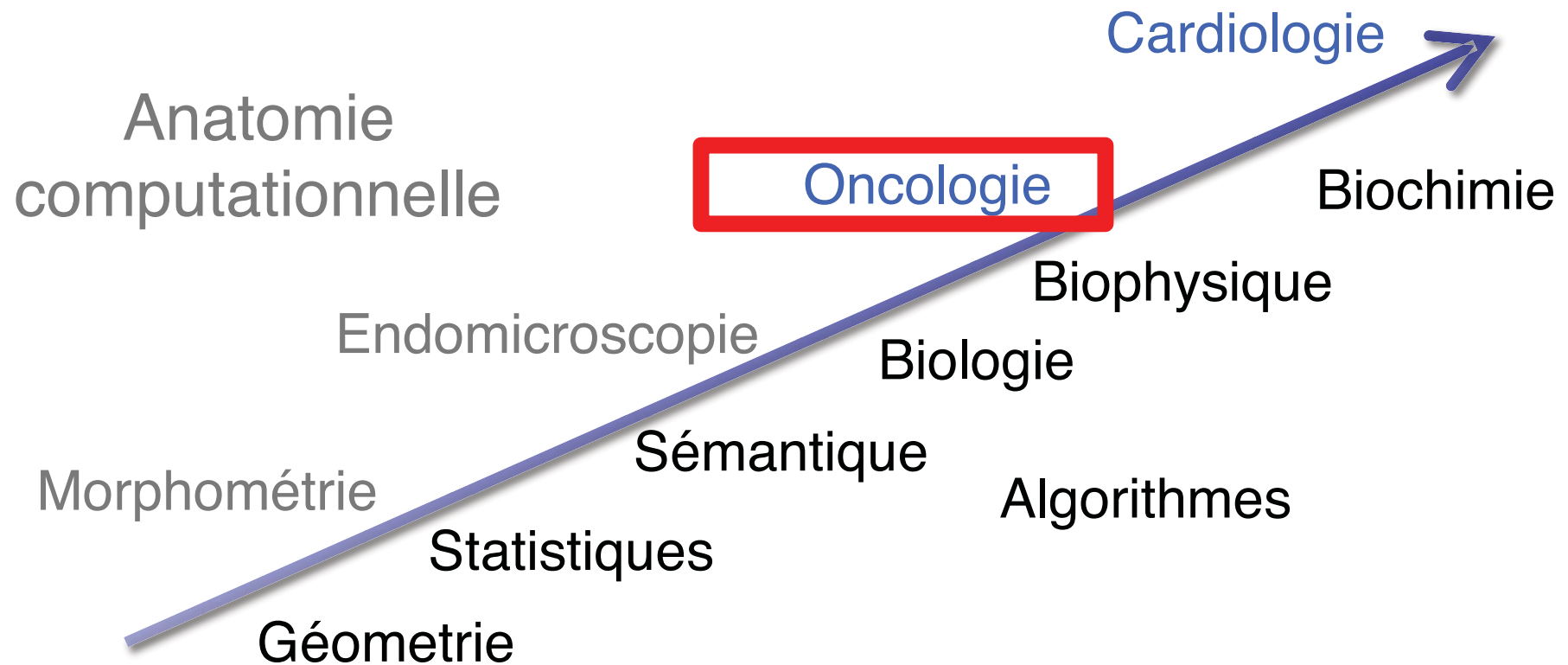
Découvrir une  
structure

**Colonic Polyps**

- **Non néoplasiques**
- **Néoplasiques**



# Physiologie computationnelle



# Tumeurs cérébrales

- **Plus rare:** 5 cas/10.000 personnes
  - Jeunes adultes: 3<sup>ème</sup> cause de décès
  - Enfants: 2<sup>ème</sup> cancer après leucémie
- IRM
- Modélisation pour
  - *Quantifier* évolution *passée*
  - *Extrapoler* infiltration *présente*
  - *Prédire* évolution *future*

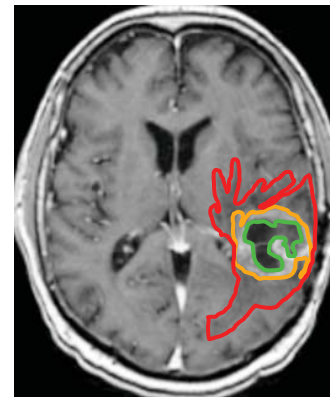
Personnaliser diagnostic et thérapie



T2



T1

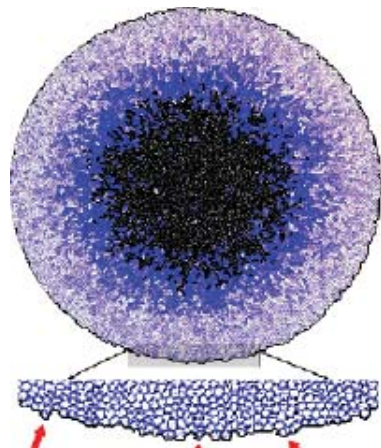


T1+ gad

# Croissance Tumorale

gènes ↔ protéines ↔ enzymes ↔ cellules ↔ tissus ↔ organes

Croissance avasculaire



Drasdo et al., Phys. Biol. 2005

Angiogenèse

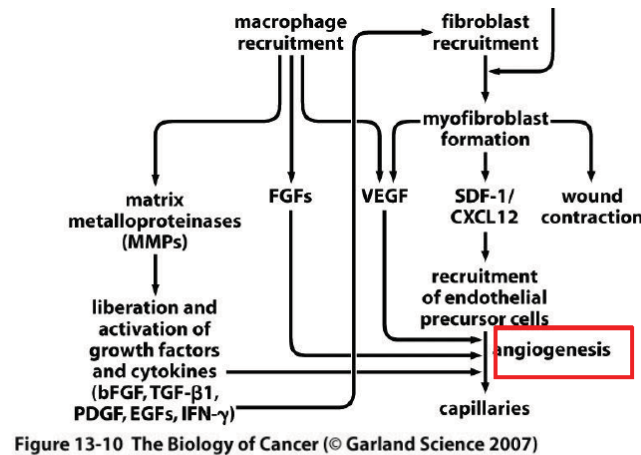
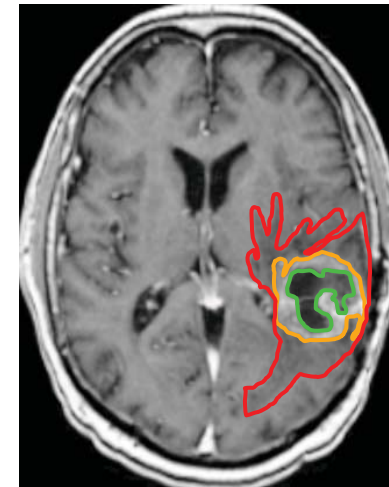


Figure 13-10 The Biology of Cancer (© Garland Science 2007)

M. Brady, IHP, 2012

Croissance vascularisée



T1+ gad

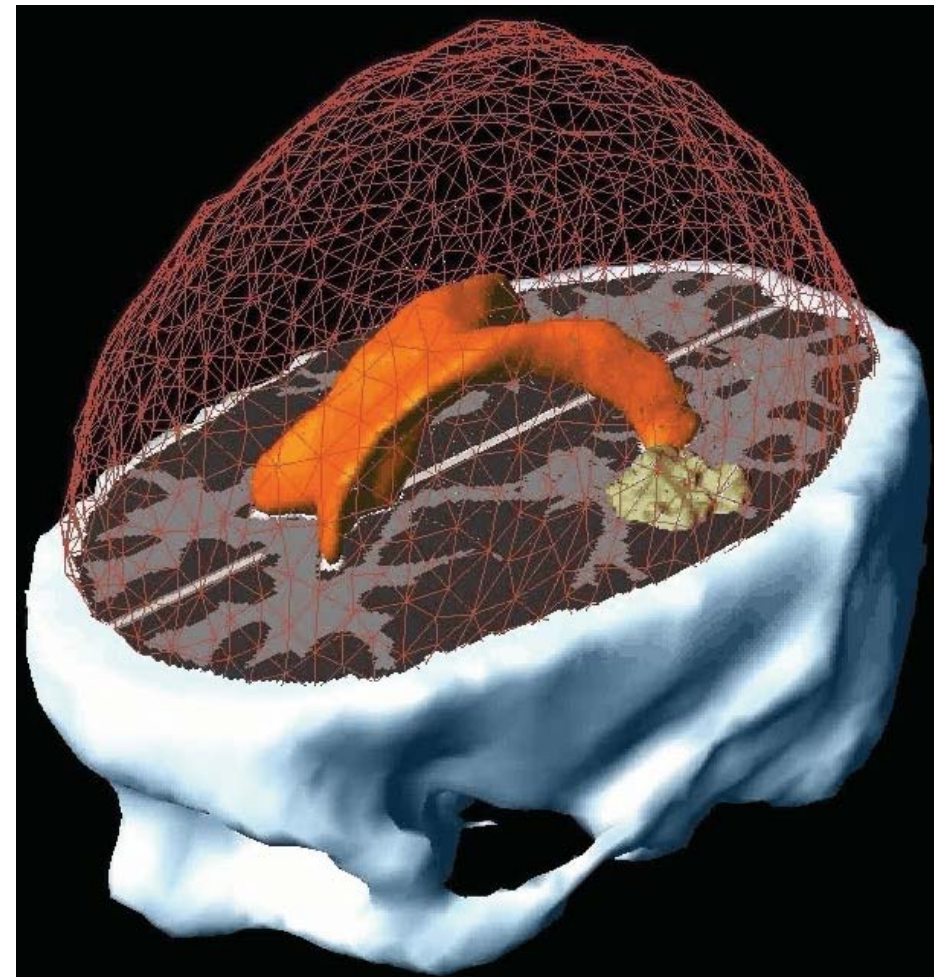
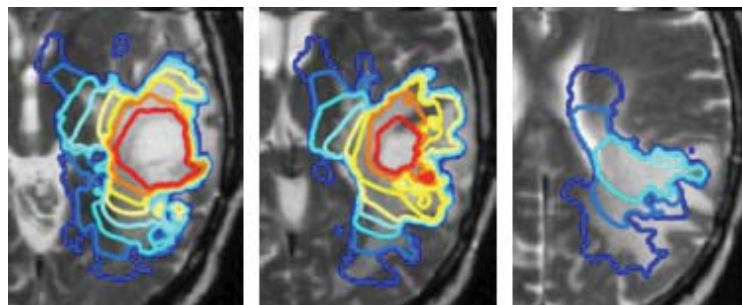
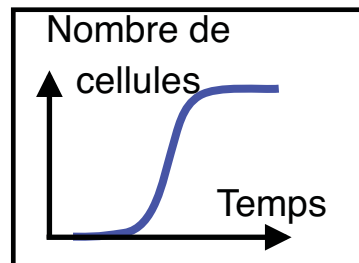
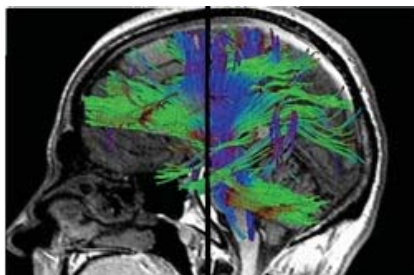
P. Tracqui, K. Swanson, H. Byrne, D. Murray, M. Chaplain, V Cristini, B. Perthame, etc.

# Modèle computationnel

$$\frac{\partial c}{\partial t} = \nabla \cdot (D \nabla c) + \rho c(1 - c)$$

Infiltration  
cellulaire  
anisotrope

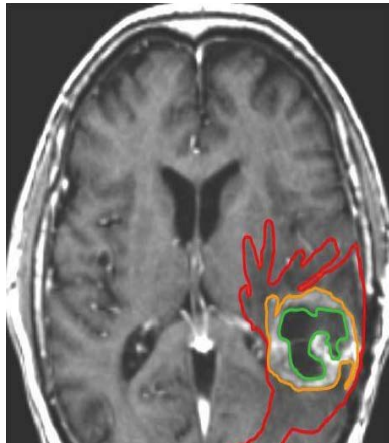
Multiplication  
cellulaire



Swanson, Alvord, Murray, *British Journal of Cancer*, 2002

O. Clatz, et al. *IEEE TMI*. 2005.

# Nécrose et vascularisation



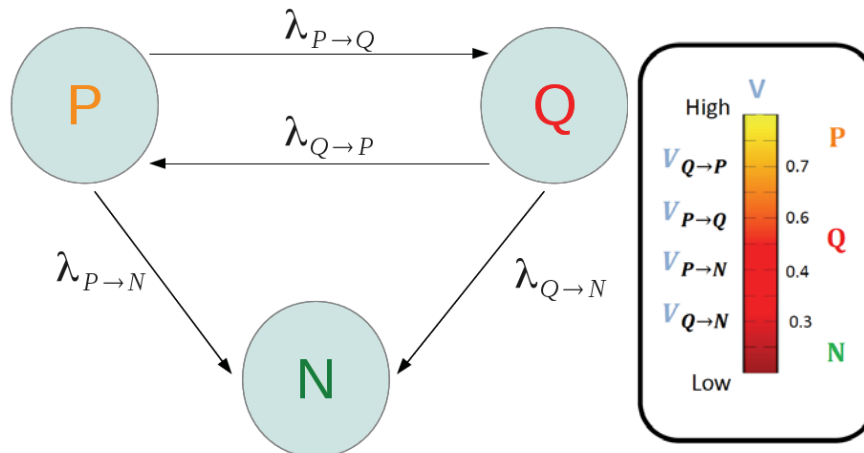
plusieurs types  
de cellules  
tumORALES

Proliférantes

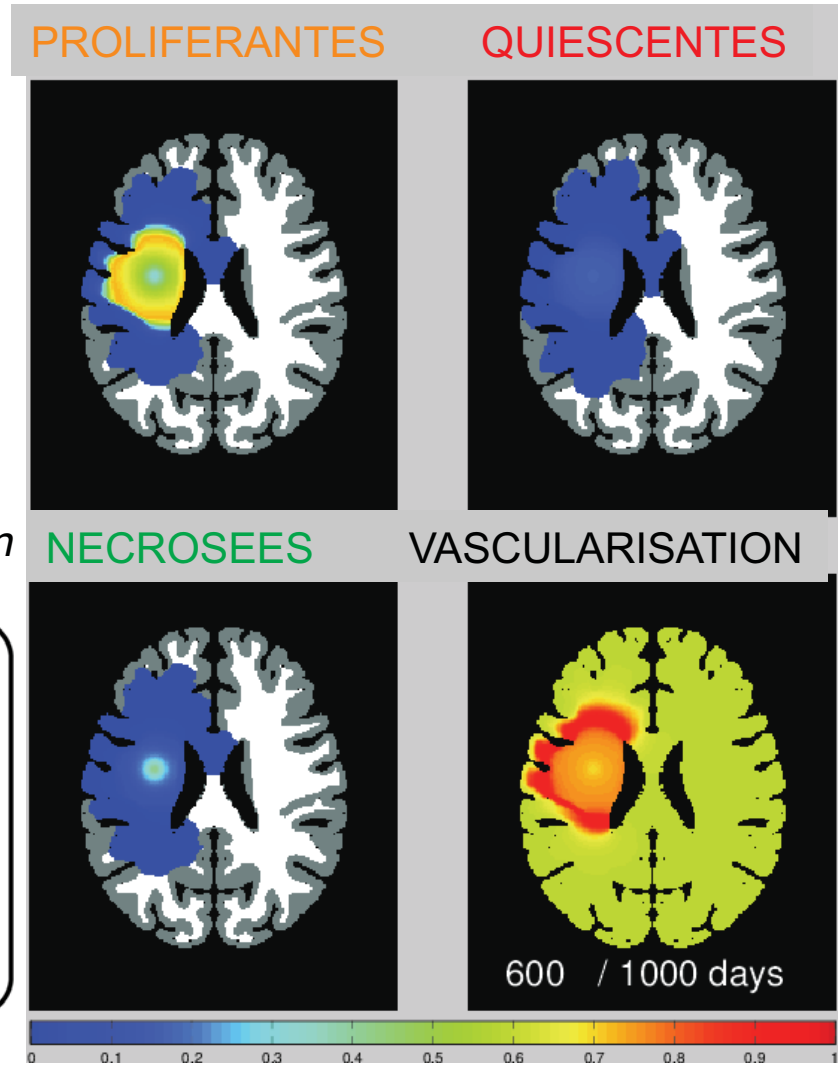
Quiescentes

Nécrosées

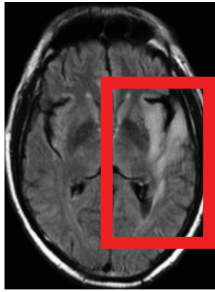
- **Transitions** : fonction de la vascularisation



- **Vascularisation** : fonction de P et Q



T. Colin, O. Saut et al., M. Le 2012



# Prédire la progression

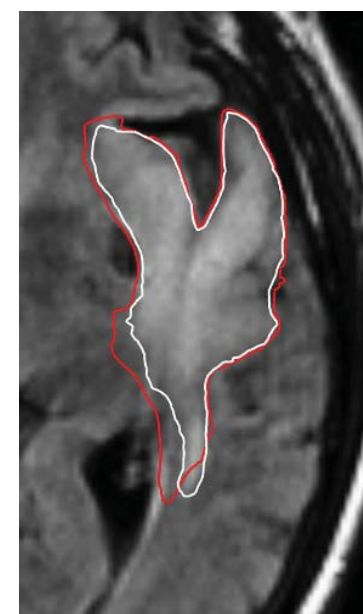
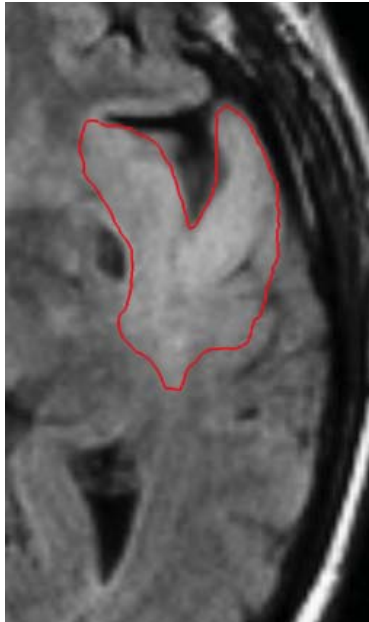
apprendre

Simulation/réalité

$T_0$

$T_0 + 7$  mois

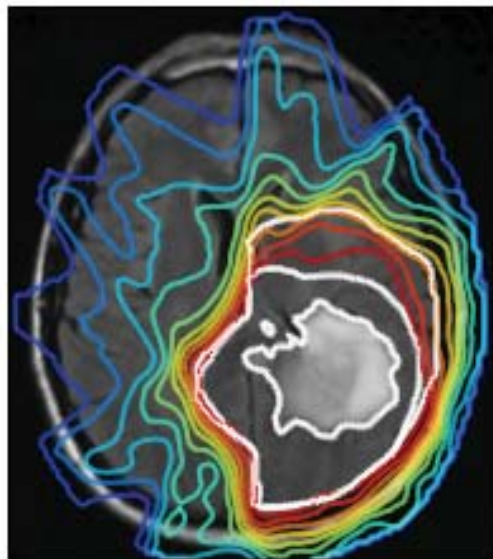
$T_0 + 13$  mois



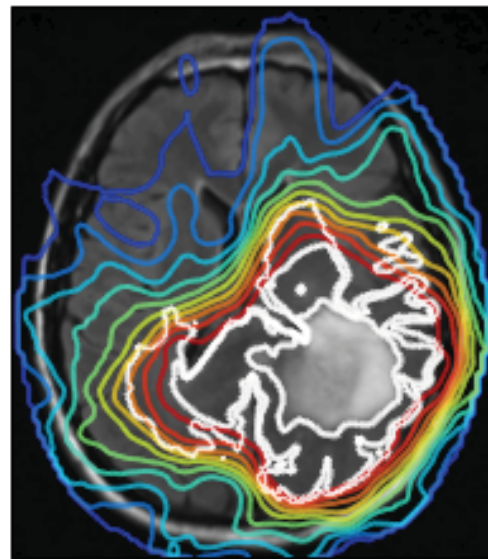
E. Konukoglu, et al.. TMI 2010.

# Radiothérapie

Dosimétrie standard  
Contours tumeurs  
+ marges 2cm



Dosimétrie optimisée  
pour le modèle de croissance  
personnalisé



MGH  
Boston



J Unkelbach et al. *Radiotherapy planning for glioblastoma based on a tumor growth model: improving target volume delineation.*  
Physics in Medicine and Biology, December 2013.

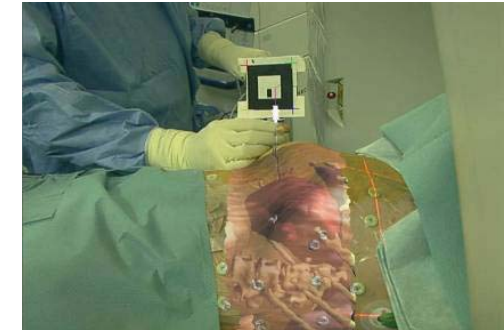
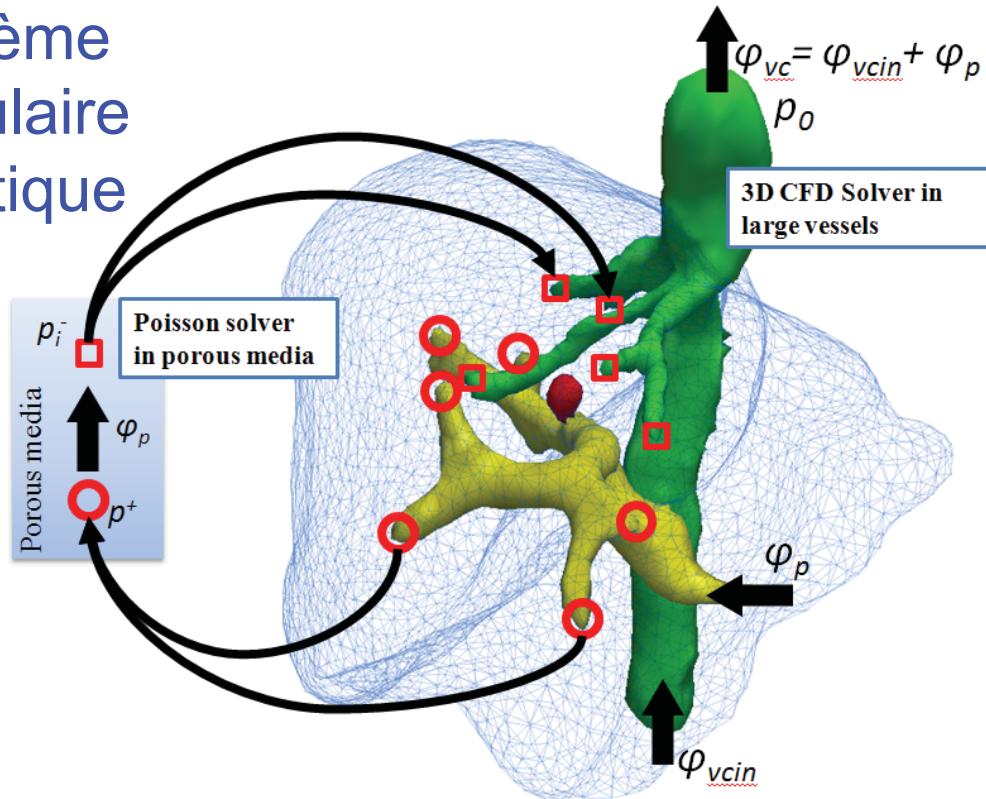


# Thermoablation

Siemens Princeton  
J. Hopkins Hospital  
Inria

## Modélisation des transports thermiques

Système  
vasculaire  
hépatique



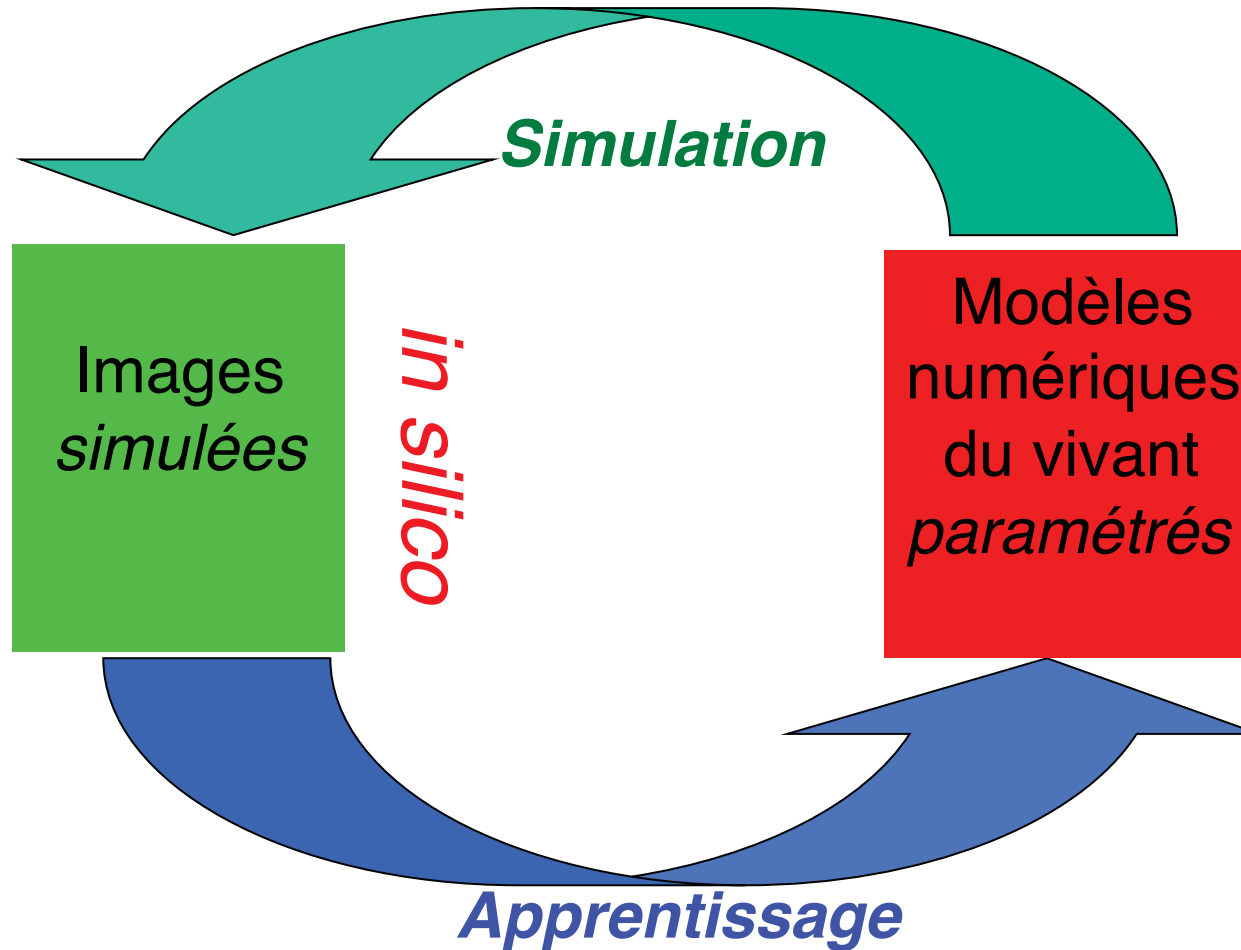
IHU Strasbourg



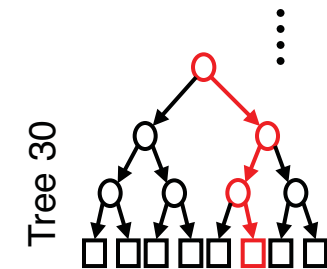
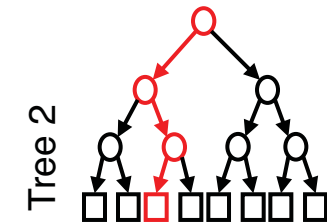
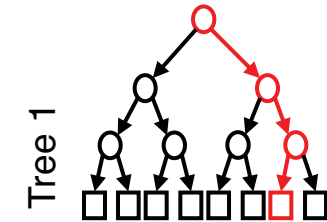
Réalité augmentée *anatomique*  
et *physiologique*

C Audigier, T. Mansi et al. *MICCAI 2013*

# Simuler pour apprendre



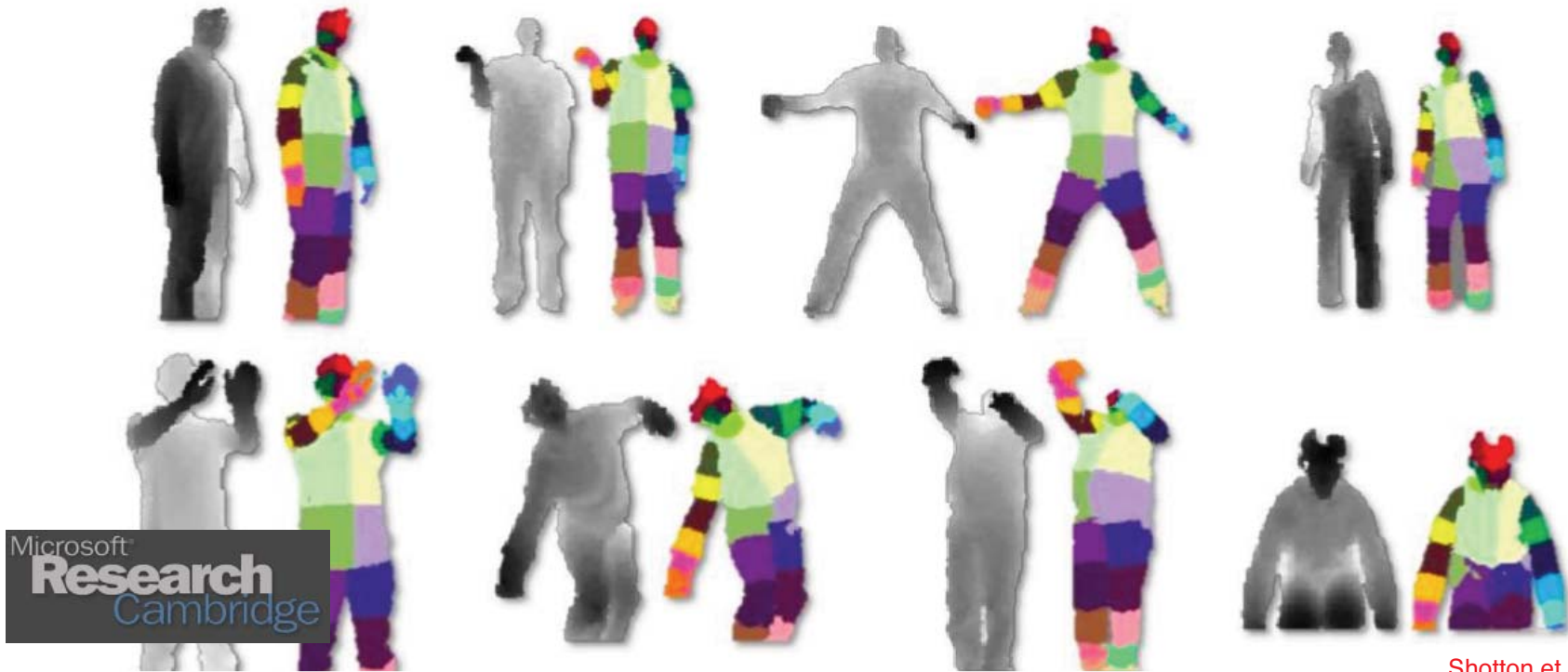
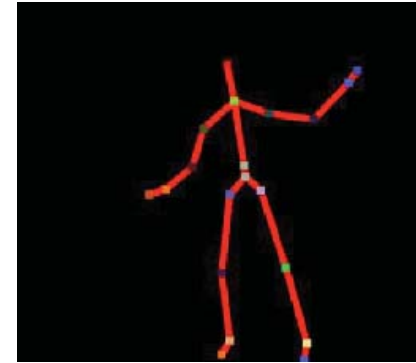
## Apprentissage statistique



A. Criminisi et al.



# Kinect



Shotton et al., 2011

# Therapixel



Nicholas Ayache  
10 avril 2014

Des images médicales au  
patient numérique

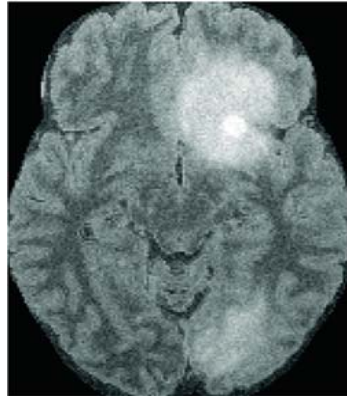


COLLÈGE  
DE FRANCE  
—1530—

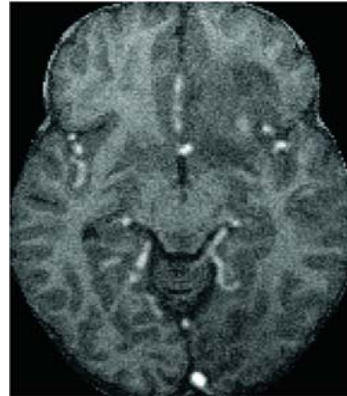
62

# Prédire

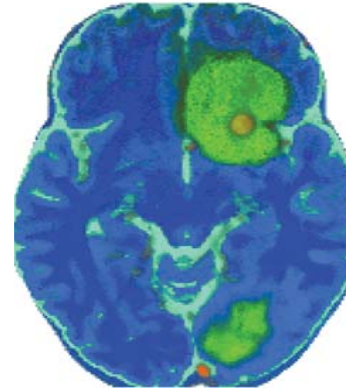
simulées



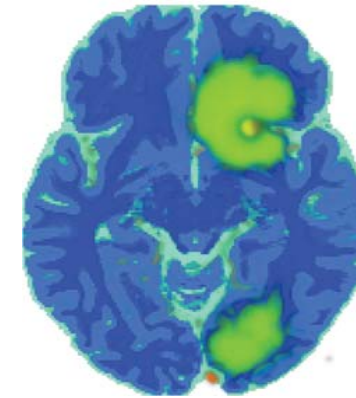
IRM Flair



T1 + Gd

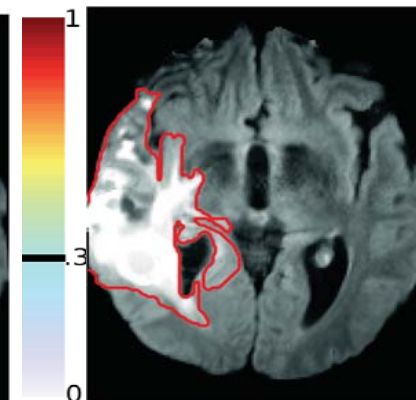
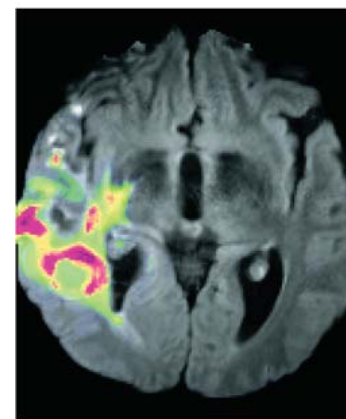
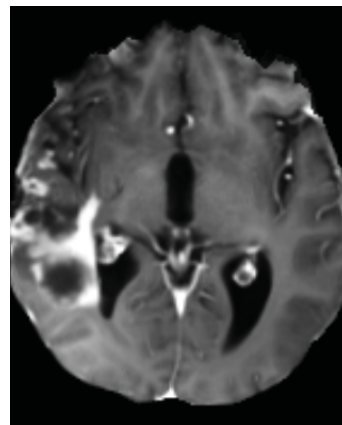
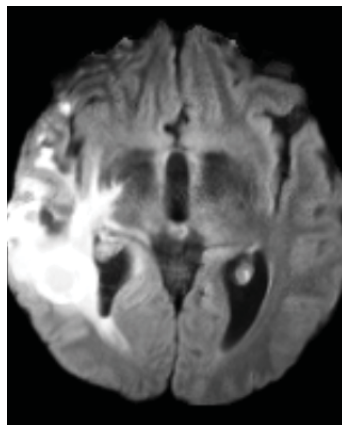


prédiction



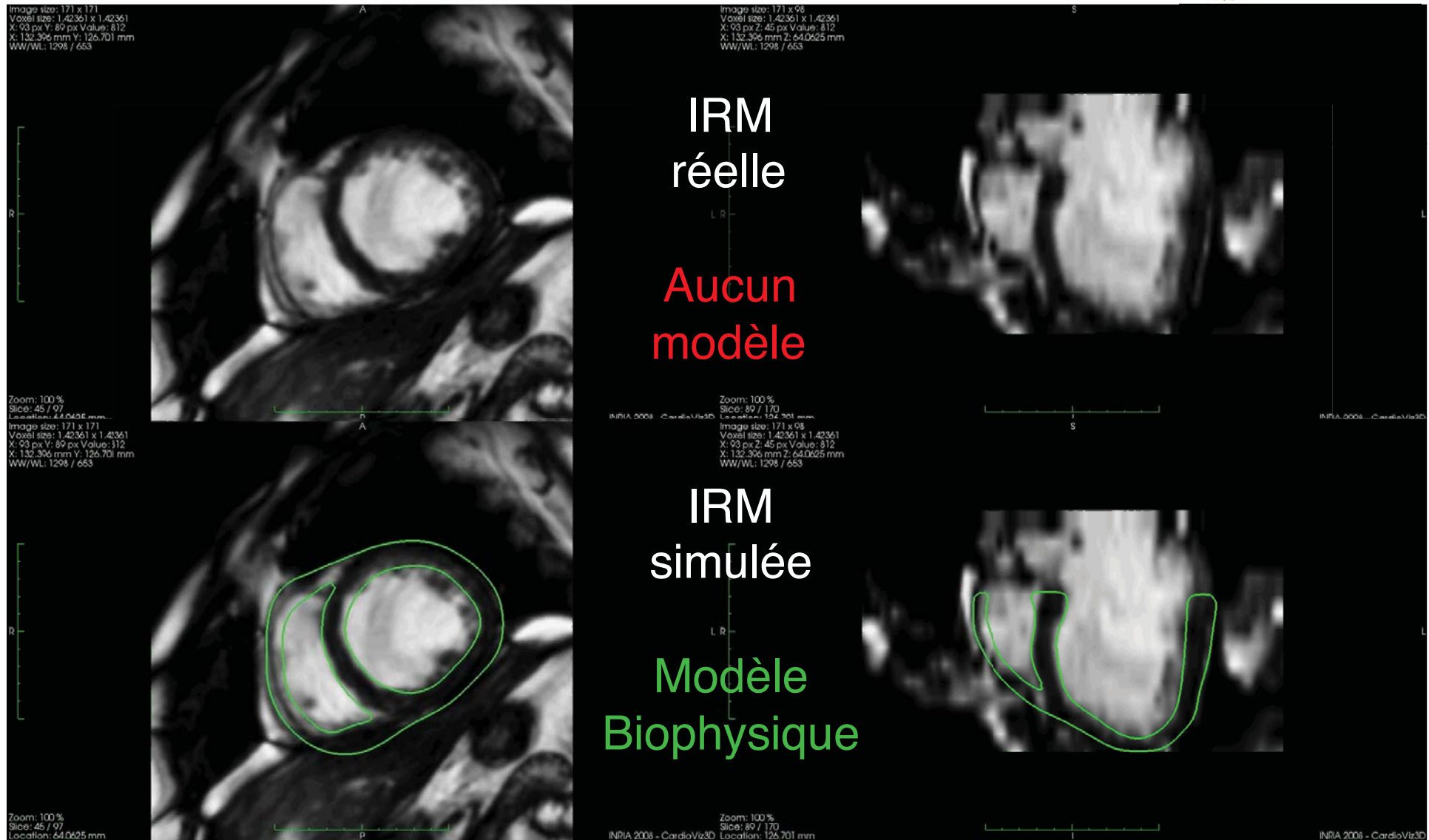
vérité

réelles



E Geremia, et a. 2012

# Simuler pour apprendre

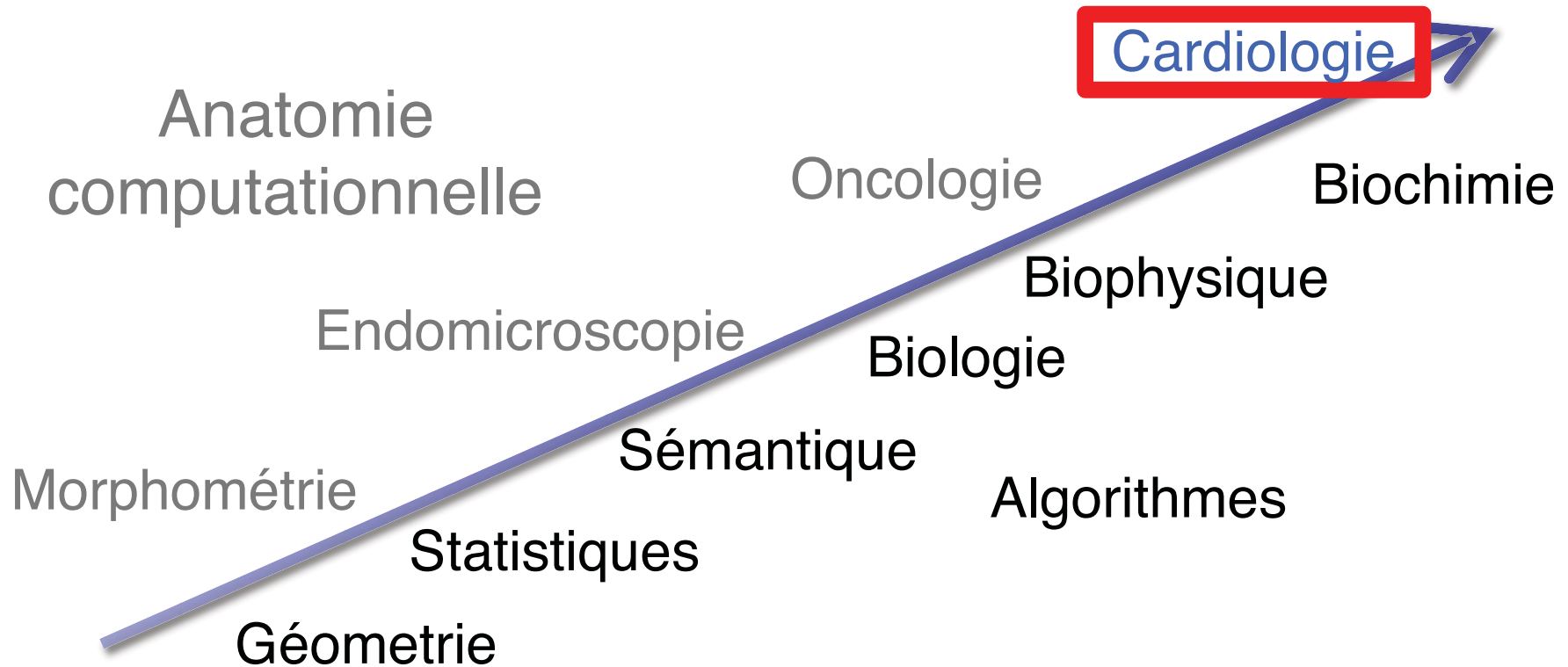


A. Prakosa et al., 2013

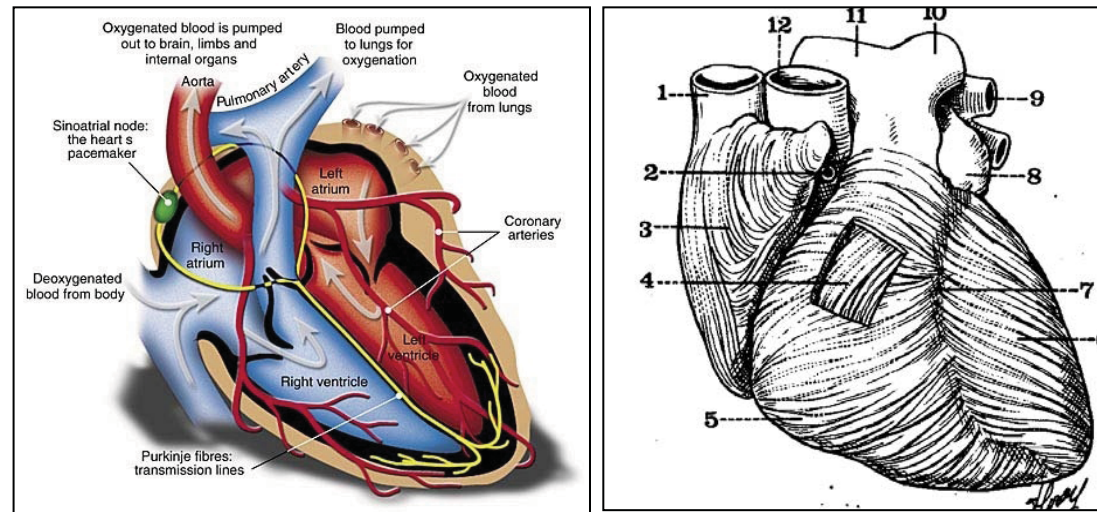
Nicholas Ayache  
10 avril 2014

Des images médicales au  
patient numérique

# Physiologie computationnelle



# Maladies cardiovasculaires

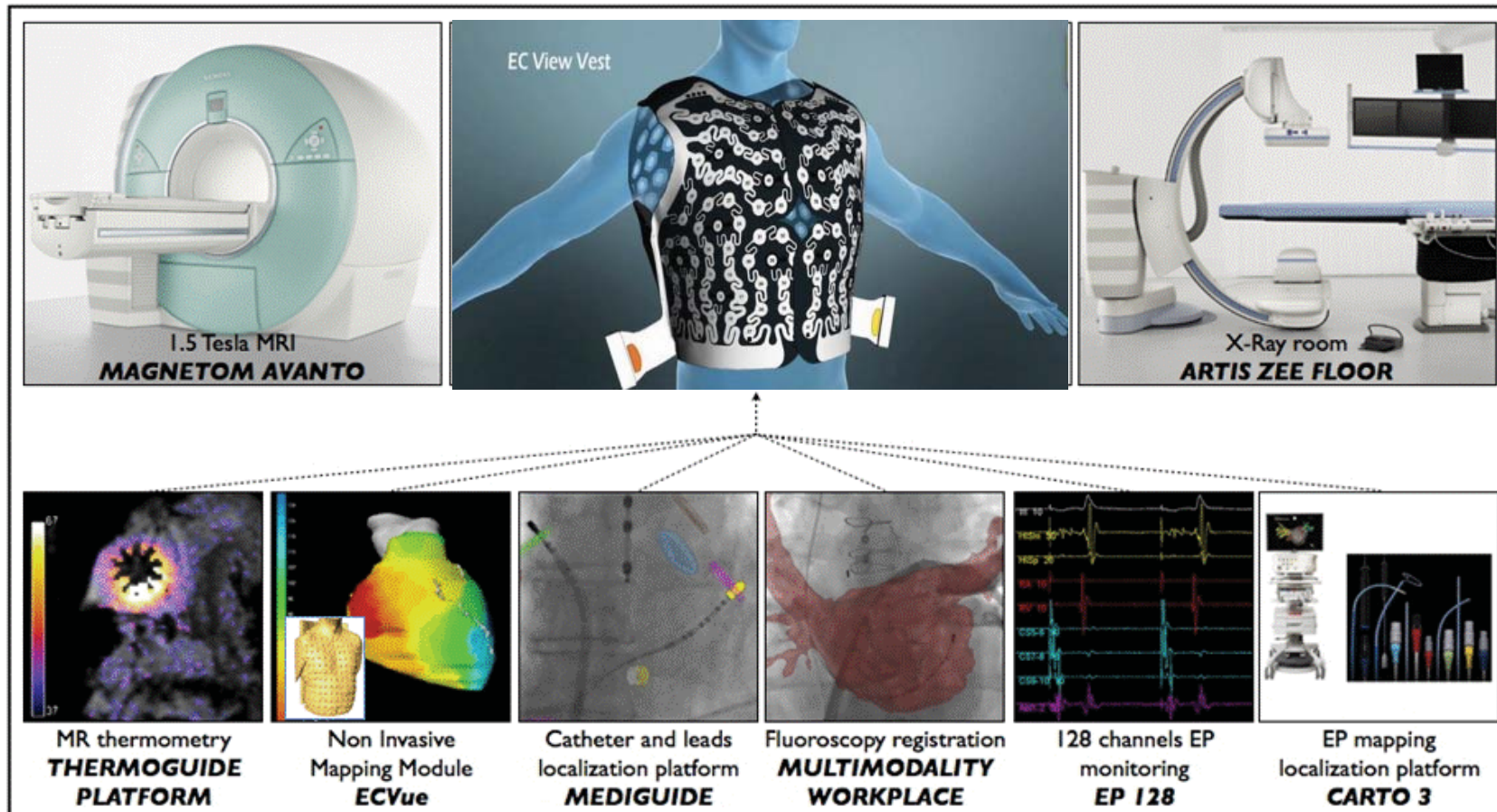


Enjeu de santé publique  
Première cause de mortalité dans le monde  
Europe : 4,3 millions de décès par an



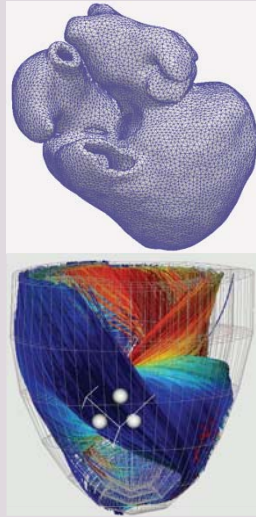
# Images et signaux cardiaques

IHU – Bordeaux  
M. Haïssaguerre, P. Jaïs

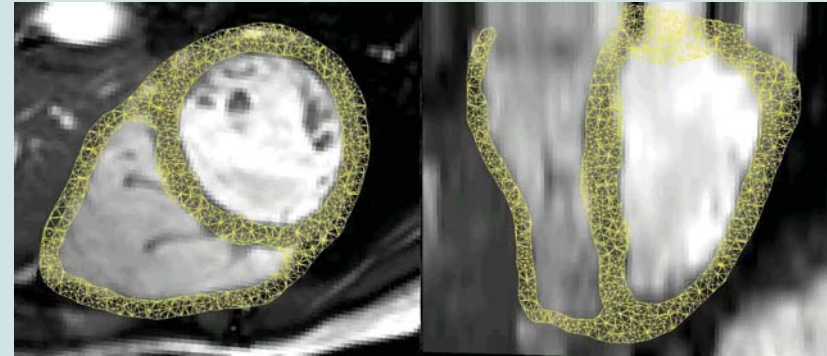


# Coeur numérique

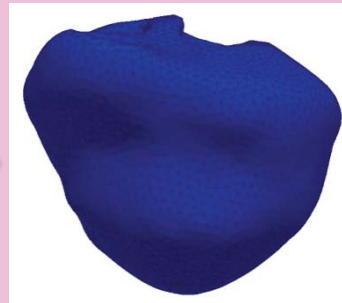
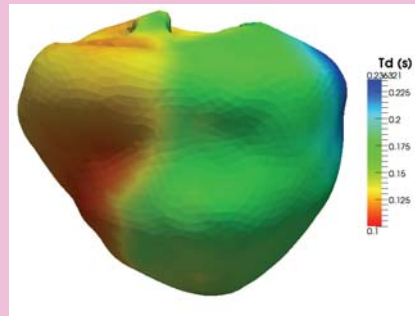
## 1. Structure



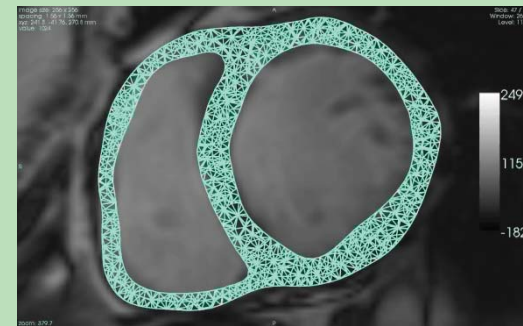
## 4. Personnalisation



## 2. Electrophysiologie

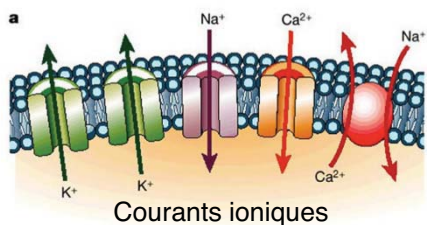


## 3. Mécanique



N. Ayache, H. Delingette, M. Sermesant. *Le cœur numérique personnalisé*. Bull. de l'Académie Nationale de Médecine, 2011.

# 2. Electrophysiologie



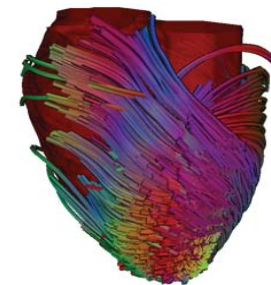
Courants entrants  
(Na<sup>+</sup>, Ca<sup>2+</sup>)

Courants sortants  
(K<sup>+</sup>)

$$\begin{cases} \partial_t u = \operatorname{div}(d_{MS} \mathbf{M} \nabla u) + \frac{z u^2 (1 - u)}{\tau_{in}} - \frac{u}{\tau_{out}} + J_{stim}(t) \\ \partial_t z = \begin{cases} \frac{(1 - z)}{\tau_{open}} & \text{if } u < u_{gate} \\ \frac{-z}{\tau_{close}} & \text{if } u > u_{gate} \end{cases} \end{cases}$$

C. Mitchell and D. Schaeffer

Matrice  $M$  :  
fibres



**Variable :**  $u$  potentiel d'action

**Paramètres :**

$d_{MS}$  coefficient de diffusion

$\tau_{open}$

$\tau_{close}$

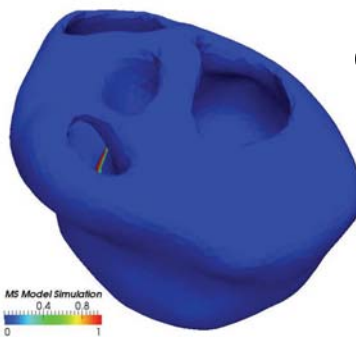
$\tau_{in}$

$\tau_{out}$

} Constantes de temps

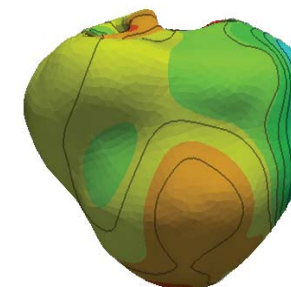
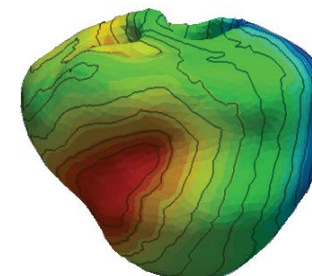
Physiome  
VPH

D. Noble, Hodgkin-Huxley, Fitzhugh-Nagamo, Luo-Rudy, Aliev-Panfilov, Trayanova, ...



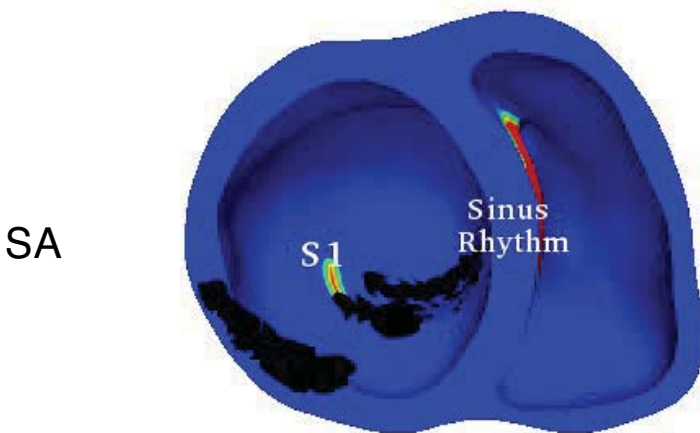
Isochrones  
dépolarisation

durée  
potentiel  
d'action

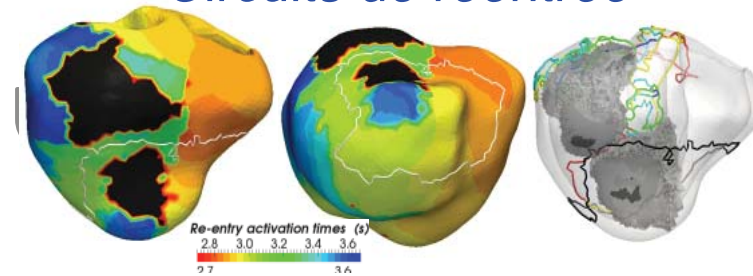


# 2. Electrophysiologie personnalisée

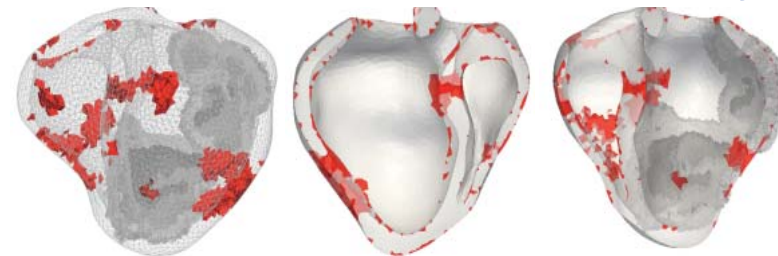
- Protocole VT-stim **simulé** à différentes fréquences



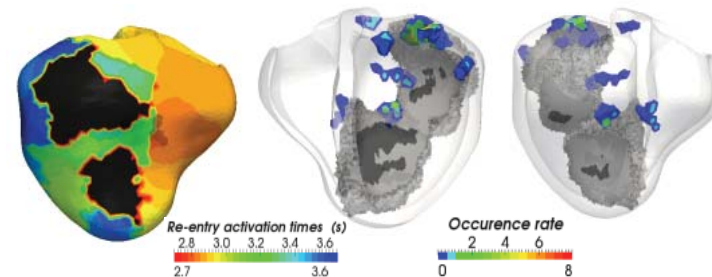
*Circuits de réentrée*



*Carte de risque d'induction tachycardie*



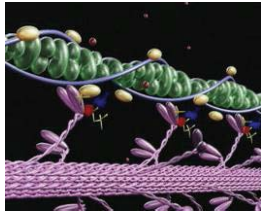
*Cibles pour l'ablation*



J Relan et al., *Royal Society Journal on Interface Focus*, 2011

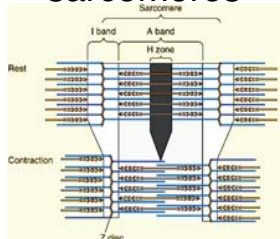
# 3. Mécanique

ATP



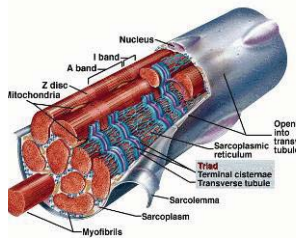
nano

sarcomères



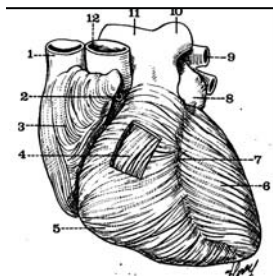
micro

fibres

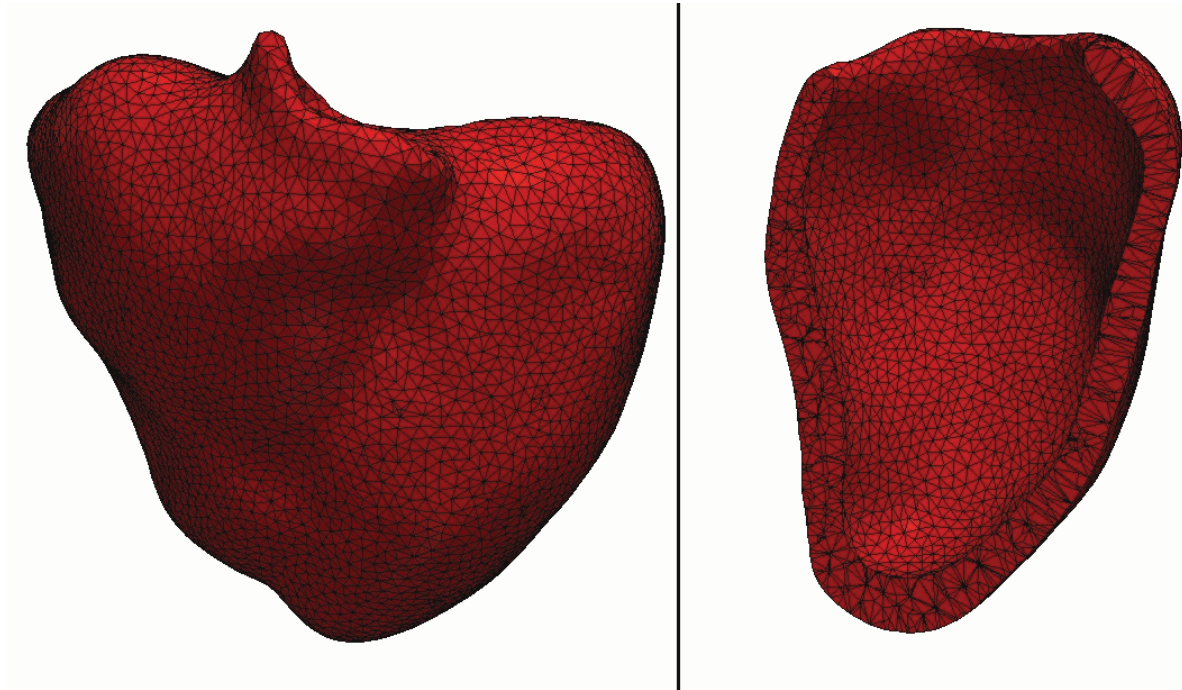


méso

organe



macro



Matériau **actif, non-linéaire, viscoelastique anisotrope incompressible**

modèles : P. Hunter, M. Nash, A. McCulloch, F. Sachse, N. Smith, M Sorine ...

*Inspiré par le modèle rhéologique de Hill-Maxwell*

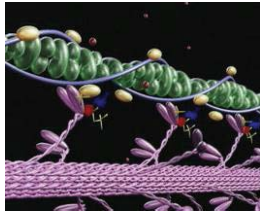
$$\begin{aligned} \rho \ddot{P} - \operatorname{div}(K_p \mathcal{E}_p + C_p \dot{\mathcal{E}}_p + \sigma_c + C_c \dot{\mathcal{E}}_c + K_c \xi_0) &= 0 \\ \partial_t K_c &= K_0 |\mathbf{u}|_+ - (|\dot{\mathcal{E}}_c| + |\mathbf{u}|) K_c \\ \partial_t \sigma_c &= \sigma_0 |\mathbf{u}|_+ - (|\dot{\mathcal{E}}_c| + |\mathbf{u}|) \sigma_c + K_c \dot{\mathcal{E}}_c \\ \sigma_c + C_c \dot{\mathcal{E}}_c + K_c \xi_0 &= K_s (\mathcal{E}_p - \mathcal{E}_c) \end{aligned}$$

$K_c$  raideur  
 $\mathbf{u}$  potentiel d'action  
 $\mathcal{E}_c$  déformation  
 $\sigma_c$  contrainte

D. Chapelle, P. Le Tallec, P. Moireau, M. Sorine, I. J. of Multiscale Computational Engineering, 2010

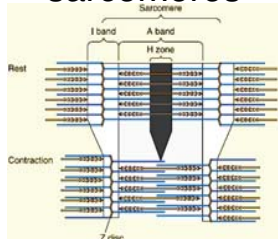
# 3. Mécanique

ATP



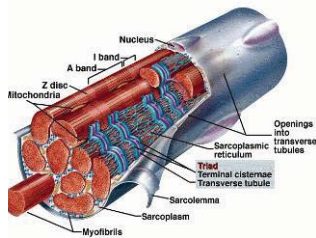
nano

sarcomères



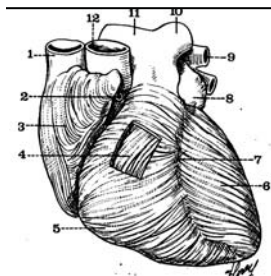
micro

fibres

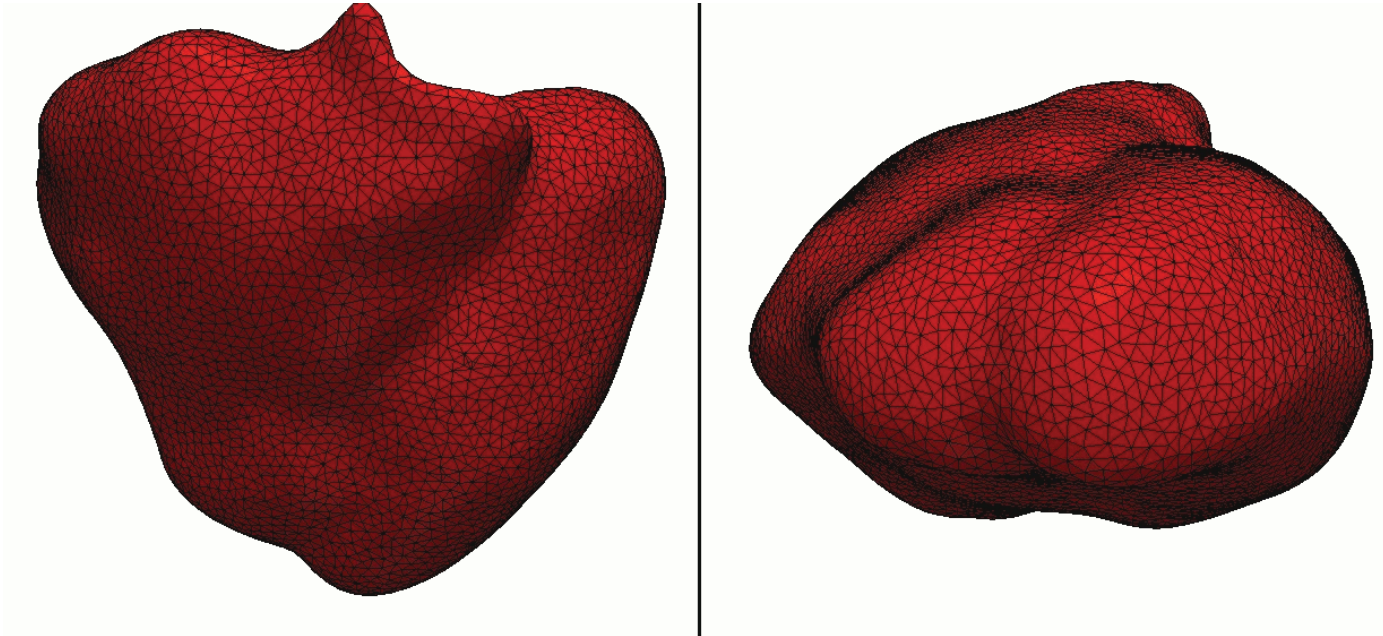


méso

organe



macro



$$\rho \ddot{P} - \text{div}(K_p \mathcal{E}_p + C_p \dot{\mathcal{E}}_p + \sigma_c + C_c \dot{\mathcal{E}}_c + K_c \xi_0) = 0$$

$$\partial_t K_c = K_0 |u|_+ - (|\dot{\mathcal{E}}_c| + |u|) K_c$$

$$\partial_t \sigma_c = \sigma_0 |u|_+ - (|\dot{\mathcal{E}}_c| + |u|) \sigma_c + K_c \dot{\mathcal{E}}_c$$

$$\sigma_c + C_c \dot{\mathcal{E}}_c + K_c \xi_0 = K_s (\mathcal{E}_p - \mathcal{E}_c)$$

$K_c$  raideur  
 $u$  potentiel d'action  
 $\mathcal{E}_c$  déformation  
 $\sigma_c$  contrainte

D. Chapelle, P. Le Tallec, P. Moireau, M. Sorine, I. J. of Multiscale Computational Engineering, 2010

# 4. Personnalisation



**KING'S**  
College  
LONDON



*The Guy's, King's and St Thomas' School of Medicine*  
Reza Razavi, K. Rhode



Chapelle, Moireau, et al., 2013  
H Delingette et al. 2012.

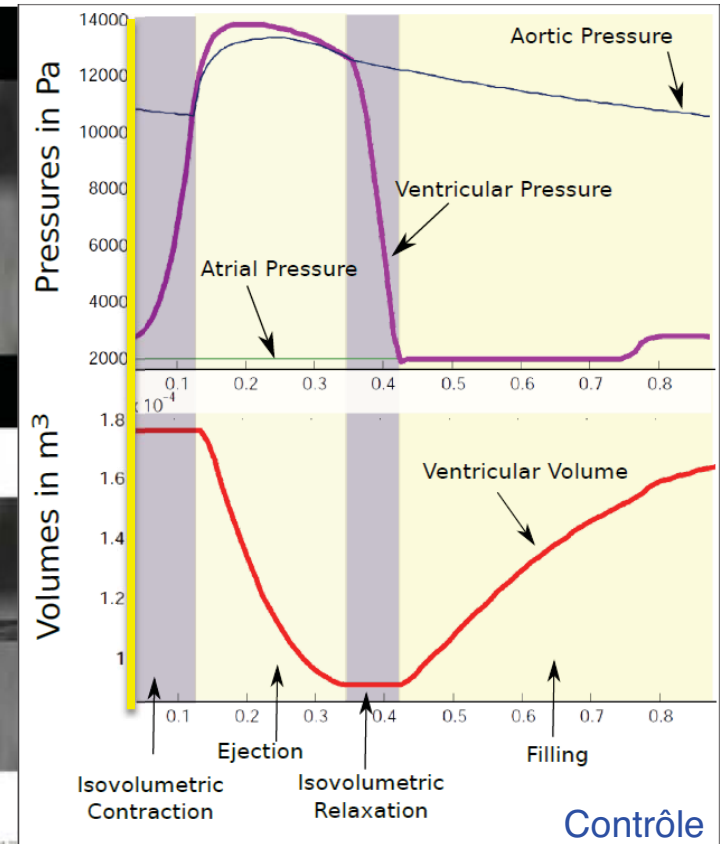
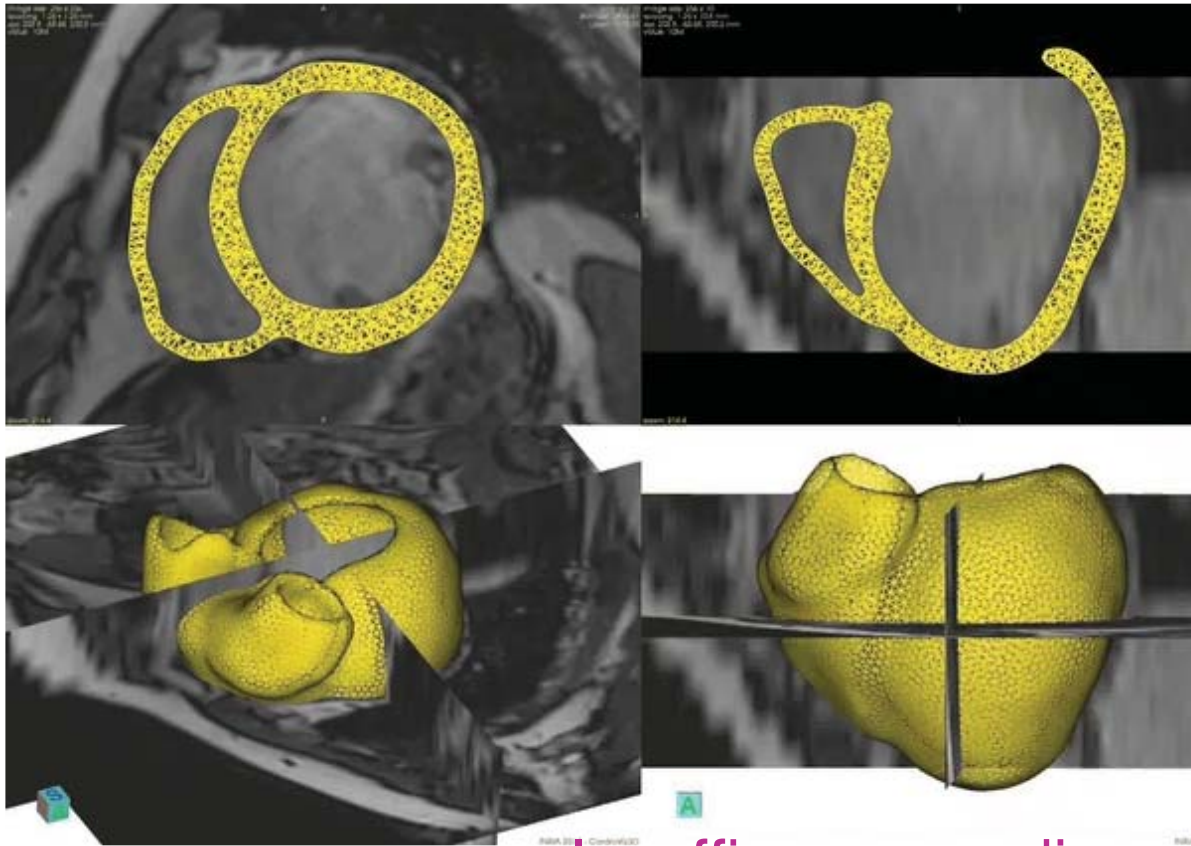
Weese, Ayache, Smith, Med Biol Eng Comput 2013

Nicholas Ayache  
10 avril 2014

Des images médicales au  
patient numérique



# Quantifier



## Insuffisance cardiaque

S Marchesseau, et al. 2012.

Nicholas Ayache  
10 avril 2014

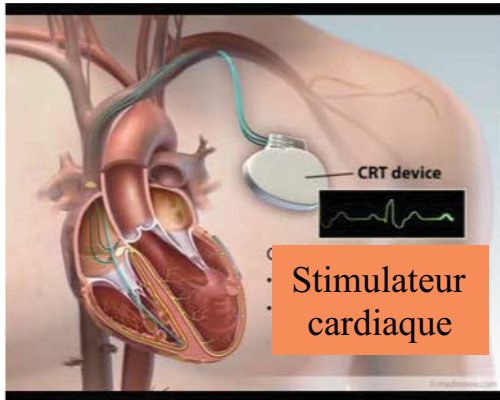
Des images médicales  
au patient numérique



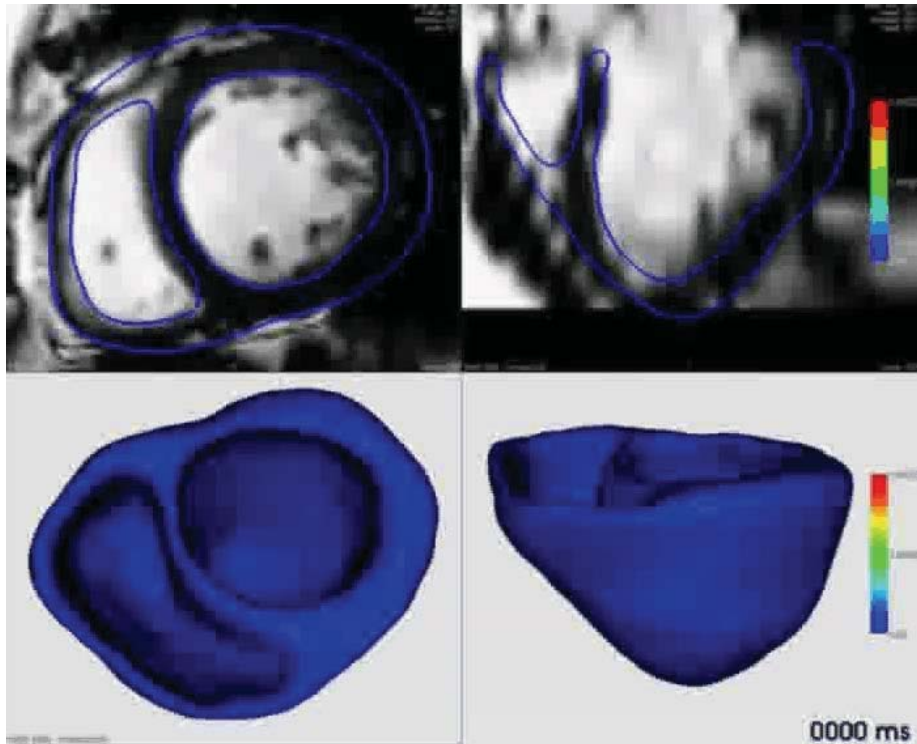
COLLÈGE  
DE FRANCE - 74  
—1530—



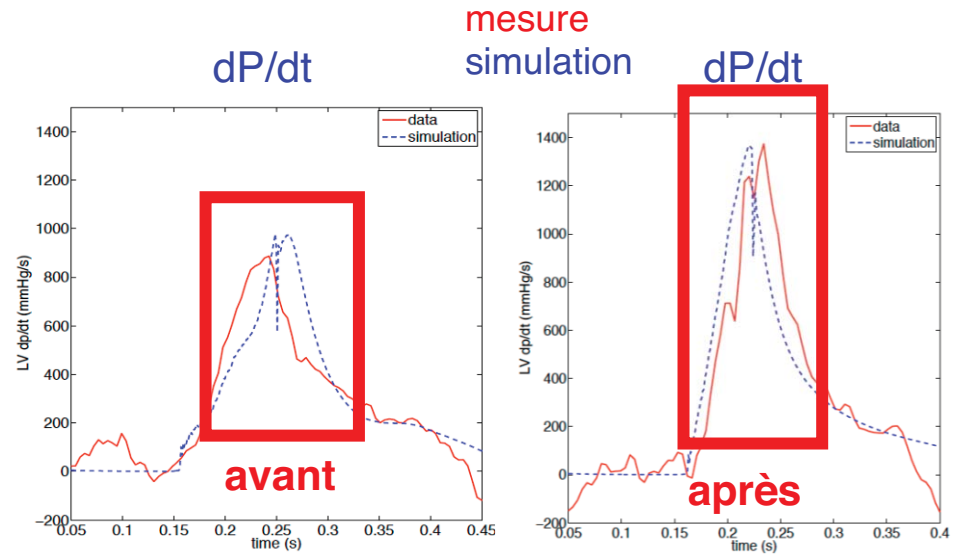
# Prédire



Stimulateur cardiaque



Bloc de branche gauche



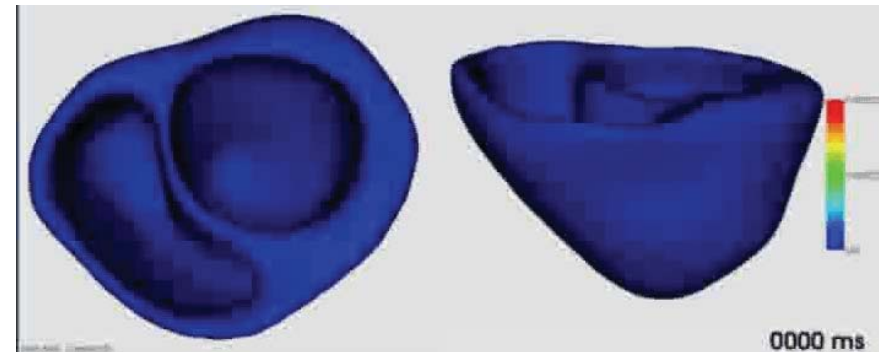
dP/dt

mesure  
simulation

dP/dt

avant

après



Resynchronisation simulée

M. Sermesant, et al., 2012

Nicholas Ayache  
10 avril 2014

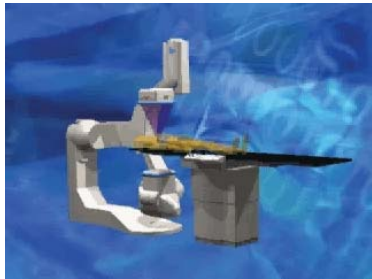
Des images médicales  
au patient numérique



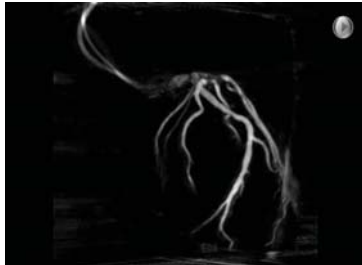
COLLÈGE  
DE FRANCE  
—1530—

75

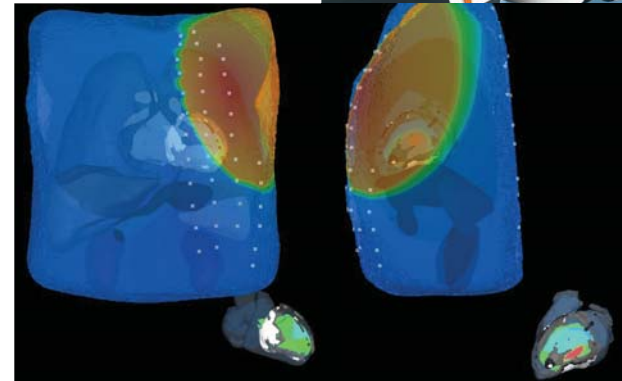
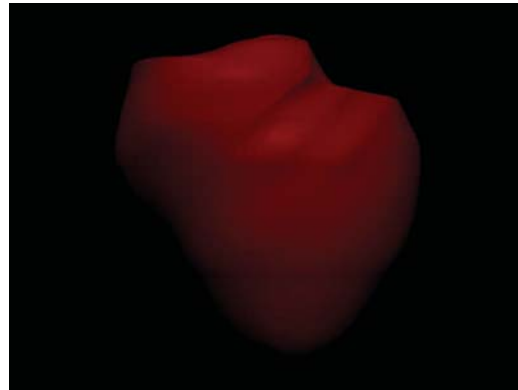
# Défis



C. Blondel et al. (GE - INRIA)

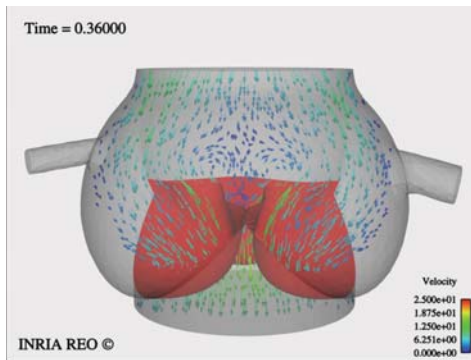
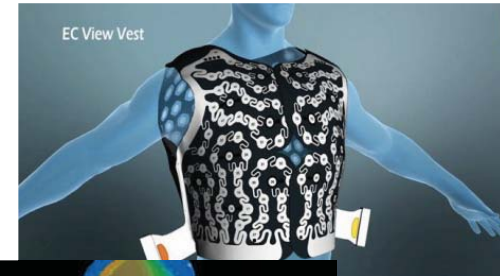


Nic Smith et al. (KCL, Oxford)

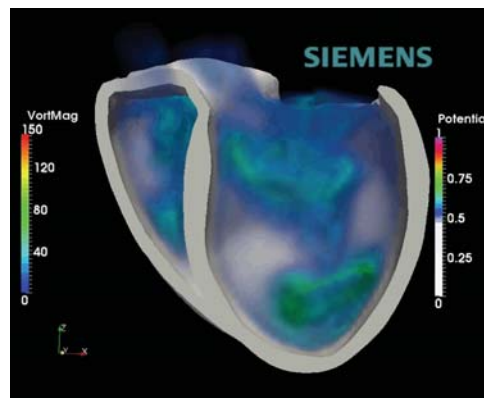


IHU  
Bordeaux

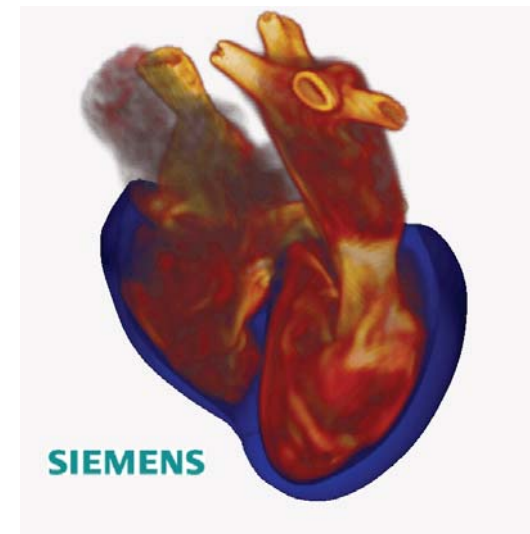
Karlsruhe



J.-F. Gerbeau, M.A. Fernández,  
REO Team, . CardioSense 3D

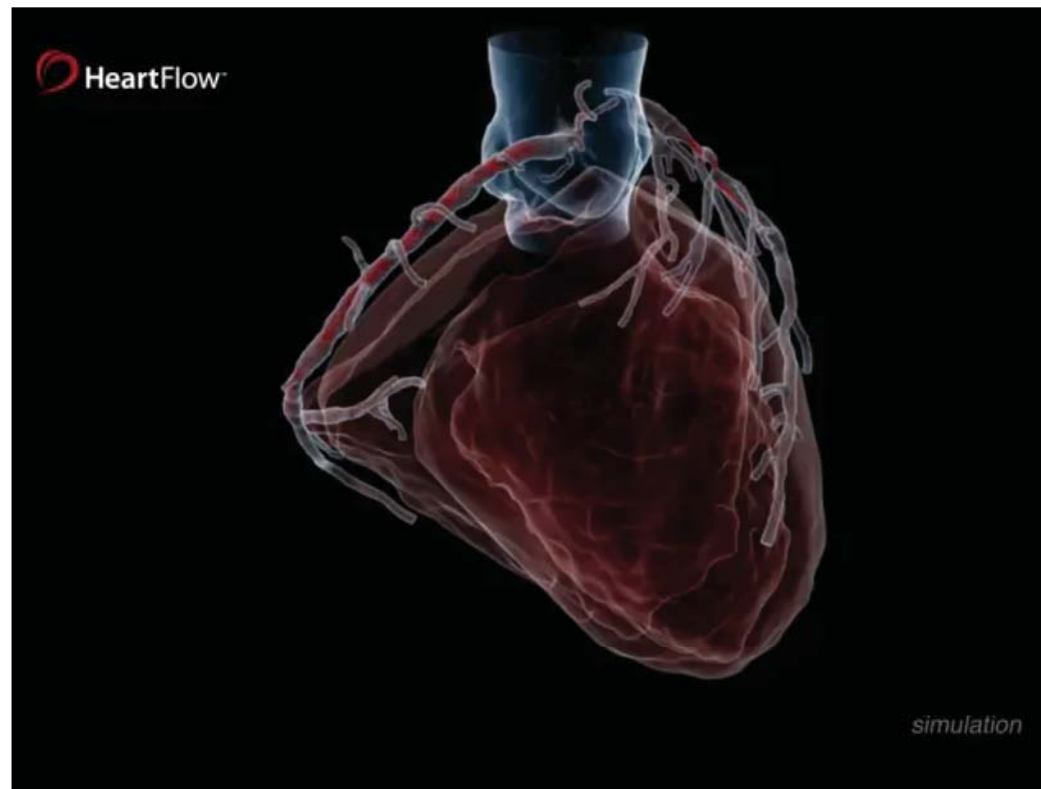


D. Comaniciu, T. Mansi  
Siemens Princeton



# Essais cliniques

- FFR – Fraction du flux de réserve coronaire calculée à partir de l'image scanner



Taylor et al., JACC, 2013



# Le patient numérique



- Changement de paradigme
  - d'une médecine plutôt normalisée et réactive
  - à une médecine plus personnalisée, prédictive & préventive.

E. Zerhouni, leçon inaugurale 2011

# Médecine computationnelle

**Recherche  
académique  
pluridisciplinaire**

**patient**

**Partenaires  
cliniques**

**Partenaires  
industriels**

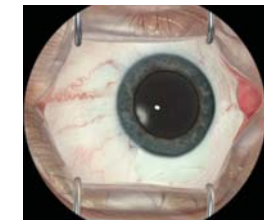
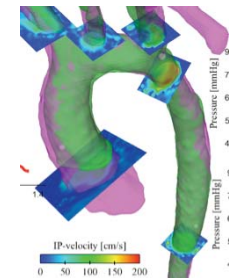
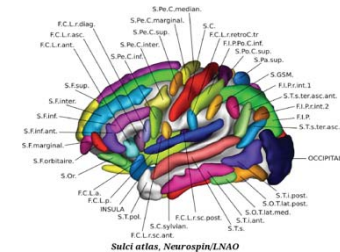
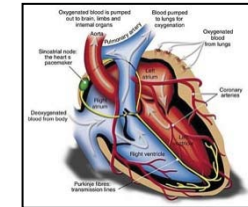
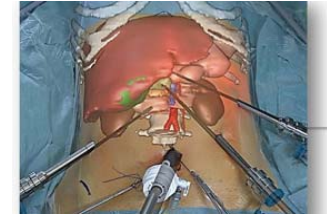
Triangle vertueux

# MICCAI Medical Image Computing and Computer Assisted Interventions



MICCAI 2012 NICE

- 29 avril 2014 **Sciences des images médicales : les grandes classes de problèmes**  
**Chirurgie du futur guidée par l'image numérique**, Jacques Marescaux, *IHU Strasbourg, IRCAD*  
**Cardiologie du futur à l'ère du patient numérique**, Michel Haïssaguerre, *CHU Bordeaux, Université Victor-Segalen, IHU LIRYC*
- 6 mai 2014 **Se repérer dans les images : recalage et segmentation**  
**Mesurer le cerveau numérique**, Jean-François Mangin, *Neurospin Saclay*  
**Reconstruction d'organes dans les formes**, Hervé Delingette, *Inria, Sophia Antipolis*
- 13 mai 2014 **Variabilité anatomique et fonctionnelle : atlas statistiques**  
**Phénotype, fonction et génotype**, Bertrand Thirion, *Inria Saclay Île-de-France, CEA, DSV, I2BM, Neurospin*  
**Statistiques de formes et variétés anatomiques**, Xavier Pennec, *Inria Sophia Antipolis*
- 20 mai 2014 **La dimension temporelle : quantifier une évolution**  
**La neuro-imagerie à l'ère du patient numérique**, Stéphane Lehericy, *IHU Pitié Salpêtrière*  
**Biomarqueurs d'imagerie dans les pathologies cérébrales**, Christian Barillot, *CNRS, Inserm, Inria Rennes*
- 27 mai 2014 **Imagerie des tumeurs : modèles biophysiques pour mesurer et prédire**  
**Neurochirurgie guidée par l'image**, Emmanuel Mandonnet, *Hôpital Lariboisière*  
**Radiothérapie guidée par l'image**, Jocelyne Troccaz, *TIMC Grenoble, CNRS*
- 03 juin 2014 **Imagerie microscopique in vivo : mosaïques numériques et indexation**  
**Les enjeux médicaux de l'endomicroscopie**, Stanislas Chaussade, *Hôpital Cochin*  
**Des étoiles aux cellules, de la recherche à l'entreprise**, Sacha Loiseau, *Mauna Kea Technologies*
- 10 juin 2014 **Le cœur numérique personnalisé : diagnostic, pronostic et thérapie**  
**Images et signaux cardiaques : état de l'art et futur**, Pierre Jaïs, *CHU Bordeaux, Université Victor-Segalen, IHU LIRYC*  
**Vers un système vasculaire numérique**, Jean-Frédéric Gerbeau, *Inria UPMC*
- 17 juin 2014 **Réalité virtuelle, simulation, et perspectives**  
**Réalité augmentée en endoscopie et chirurgie**, Luc Soler, *IRCAD/IHU, Strasbourg*  
**Simulation en médecine : présent et futur**, Stéphane Cotin, *Inria*



# Colloque 24 Juin

## 09h10 Biophysical Models for Cancer Imaging

Michael Brady, *University of Oxford, United Kingdom*

## 09h50 Learning Clinical information from Medical Images

Daniel Rueckert, *Imperial College London, United Kingdom*

## 10h30 Spatiotemporal Analysis of Brain Development and Disease Progression

Guido Gerig, *University of Utah, United States*

## 11h10 Break

## 11h20 Decision Forests in Medical Image Analysis

Antonio Criminisi, *Microsoft Research, United Kingdom*

## 12h00 Computational Physiology: Connecting Molecular Systems Biology with Clinical Medicine

Peter Hunter, *University of Auckland, New Zealand*

## 14h10 Toward a Statistical Neuroscience

Olivier Faugeras, *Inria, Université de Nice Sophia Antipolis*

## 14h50 Model-Based Biomedical Image Analysis

James Duncan, *Yale University, United States*

## 15h30 Multi-Scale Image-Guided Interventions

David Hawkes, *University College London, United Kingdom*

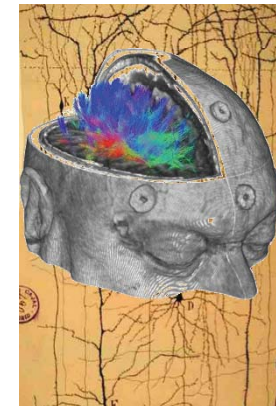
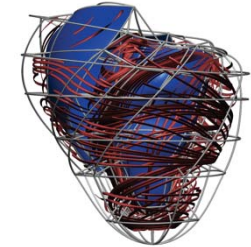
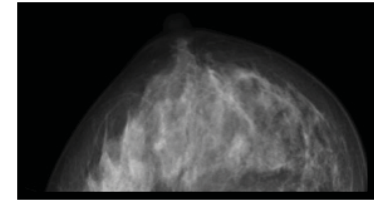
## 16h10 Break

## 16h20 Augmented Reality in the Operating Room

Nassir Navab, *Tech. Univ. Munich, Germany & J. Hopkins Univ., United States*

## 17h00 Towards Image-Based Personalized Medicine

Dorin Comaniciu, *Siemens Corporate Technology, United States*





# Remerciements

- Assemblée des professeurs
- Inria
- Intervenants séminaires et colloque
- Equipe de recherche Asclepios, doctorants
- Collaborateurs académiques, cliniques, industriels
- Famille et amis

